



RECORD OF DECISION FOR AREA B (PICA 205) GROUNDWATER

PICATINNY ARSENAL NEW JERSEY

FINAL

FEBRUARY 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

1,2-DCE	1,2-dichloroethene	LH	light hydrocarbon
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo -p-dioxin	LOC	Level of Concern
		LTM	long-term monitoring
		LUC	Land Use Control
AEDB-R	Army Environmental Data Base-Restoration	MCL	Maximum Contaminant Level
AR	Army Regulation	µg/L	micrograms per liter
ARAR	Applicable or Relevant and Appropriate Requirement	mg/kg	milligrams per kilogram
ARI	Additional Remedial Investigation	MNA	Monitored Natural Attenuation
Army	U.S. Department of the Army	Msl	mean sea level
		NCP	National Oil and Hazardous Substances Pollution Contingency Plan
BERA	Baseline Ecological Risk Assessment	NJ	New Jersey
bgs	below ground surface	NJDEP	New Jersey Department of Environmental Protection
CDI	Chronic Daily Intake	NJGWQS	New Jersey Ground Water Quality Standard
CEA	Classification Exception Area	NPL	National Priorities List
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980	O&M	Operation and Maintenance
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System	ORC	Oxygen Release Compound
		ORP	Oxidation Reduction Potential
cis-1,2-DCE	cis-1,2-dichloroethene	PCB	Polychlorinated Biphenyl
COC	Contaminant of Concern	PCE	Tetrachloroethene
COPC	Constituent of Potential Concern	PF	Pneumatic Fracturing
CSM	Conceptual Site Model	PVC	Polyvinyl Chloride
CVOC	chlorinated volatile organic chemical		
		RAB	Restoration Advisory Board
DDT	dichlorodiphenyltrichloroethane	RAO	Remedial Action Objective
DGI	Data Gap Investigation	RC	remedy complete
DO	Dissolved Oxygen	RD	Remedial Design
DPT	Direct Push Technology	RfD	Reference Dose
		RG	Remedial Goal
EcoCOPC	Ecological Chemical of Potential Concern	RI	Remedial Investigation
ER, A	Environmental Restoration, Army	RIP	Remedy in Place
ERA	Ecological Risk Assessment	ROD	Record of Decision
		ROI	Radius of Influence
FS	Feasibility Study	SARA	Superfund Amendments and Reauthorization Act of 1986
ft.	foot / feet	SF	Slope Factor
ft/day	feet per day		
ft/ft	feet per foot	TAL	Target Analyte List
GIS	Geographic Information System	TCE	Trichloroethene
GPB	Green Pond Brook	TOC	Total Organic Carbon
GWQS	Groundwater Quality Standards	USEPA	U.S. Environmental Protection Agency
HE	High Explosives	UXO	Unexploded Ordnance
HHRA	Human Health Risk Assessment		
HI	Hazard Index	VC	Vinyl Chloride
HQ	Hazard Quotient	VOC	Volatile Organic Compound
HRC	Hydrogen Release Compound		
ICFKE	ICF Kaiser Engineers	WRA	Well Restriction Area
IRP	Installation Restoration Program	ZVI	Zero-valent Iron

1.0 PART 1: DECLARATION

1.1 SITE NAME AND LOCATION

Picatinny Arsenal is formally designated as U.S. Department of the Army (Army) Installation Management Command Northeast Regional Garrison Office (Picatinny). It is located in North Central New Jersey (NJ), in Rockaway Township, Morris County, near the Town of Dover. The facility was included on the National Priorities List (NPL) in March of 1990 and assigned a Comprehensive Environmental Response, Compensation, and Liability Identification System (CERCLIS) number of NJ3210020704.

This Record of Decision (ROD) specifically addresses groundwater contamination at Area B (**Figure 1**). Area B includes two study sites, Site 20 (PICA-063) and Site 24 (PICA-066). Because Site 20 is completely contained within the boundaries of Site 24, these sites are considered one site (Site 20/24) for scoping and investigation purposes. Groundwater within Area B has been separated from the remaining environmental media administratively, and is the subject of this ROD. The Army maintains a comprehensive database of sites that are being addressed within its Installation Restoration Program (IRP) called Army Environmental Data Base-Restoration (AEDB-R). Area B groundwater is designated in the AEDB-R as PICA-205.

1.2 STATEMENT OF BASIS AND PURPOSE

This ROD presents the selected remedy for Area B groundwater at Picatinny. The remedial actions have been selected in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and to the greatest extent possible, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The information supporting the decisions on the selected remedial actions is contained in the administrative record file for the site. These decisions have been made by the Army and the U.S. Environmental Protection Agency (USEPA). Comments received from the New Jersey Department of Environmental Protection (NJDEP) were evaluated and considered in selecting the final remedy. NJDEP concurs with the selected remedy.

1.3 ASSESSMENT OF THE SITE

The response action selected in this ROD will protect public health and welfare and the environment from actual or threatened releases of hazardous substances into the environment.

1.4 DESCRIPTION OF THE SELECTED REMEDY

The remediation of Area B groundwater pursuant to this ROD is part of a comprehensive environmental investigation and remediation process currently being performed at Picatinny. The remedial action for soil, surface water, and sediment at Site 20/24 was completed in 2003 and was accepted by the USEPA and NJDEP (USEPA 2005). Other areas at Picatinny are being considered separately, and remedies for these areas are presented in separate documents.

The Feasibility Study (FS) for Area B groundwater identified volatile organic compounds (VOCs) as the contaminants of concern (COCs) targeted for remediation. Investigative studies at Area B indicate that the extent of groundwater contamination at Area B exceeding the remediation goals covers an area of approximately five acres. The remedial alternative selected to protect human health and the environment for Area B groundwater consists of the following specific components:

- Implementation of in situ enhanced bioremediation within a shortened/expedited timeframe. This alternative will achieve compliance with groundwater Remedial Action Objectives (RAOs) within seven (7) years. Additionally, to assure implementation of the best, most expedited, enhanced bioremediation program possible within the selected remedy, the ROD provides for further flexibility than originally outlined in the Proposed Plan. This flexibility relates to selection of both the preferred biostimulant (reagent), and the preferred method of subsurface delivery of the reagent to meet the stated cleanup time.
- Implementation of existing Institutional Restrictions: Land Use restrictions (Controls) (LUCs) are required as part of this alternative because contamination will remain on site during implementation of

the in situ enhanced bioremediation of Area B groundwater. Land use restrictions prevent human exposure to contaminated groundwater and protect structures associated with the remedial technologies. The area to be addressed by LUCs is depicted in **Figure 2**.

- **Performance Monitoring:** During implementation of the technology, performance monitoring of groundwater will be performed at regular intervals to assure progress toward RAO achievement. In addition, a post-remediation groundwater monitoring program will be conducted. Natural attenuation parameters will be included in the suite of analytes to enable assessment of natural attenuation processes.
- **Surface Water Monitoring:** The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria. Because of the interconnectivity of groundwater and surface water in Area B and the limited exceedances historically observed in surface water, surface water criteria are expected to be met quickly as a result of groundwater remedy implementation.
- **Public awareness** of the hazards present at the site through public meetings and posting of signs, as required.
- **Outlining emergency measures** and identifying and updating existing emergency provisions, in the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment.
- **Installation of new groundwater monitoring wells and/or injection points or wells**, and associated unexploded ordnance (UXO) avoidance techniques (as required). The discovery of potentially live buried munitions and uncased high explosives necessitates the UXO avoidance measures.

The CERCLA-required five (5) year reviews will be an integral part of a completeness determination for the remedy.

1.5 STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, complies with Federal and State laws and regulations that are applicable or relevant and appropriate to the remedial actions, and is cost effective.

The statutory preference for treatment of Area B groundwater is satisfied by the selected remedy in that active treatment of contaminants in the groundwater will be accomplished through enhanced bioremediation. The selected remedy for Area B groundwater is expected to be capable of meeting the remediation goals within a seven-year timeframe; a statutory review will be conducted within five years after initiation of the remedial action to ensure that the selected remedy is, or will be, protective of human health and the environment, and is functioning as anticipated.

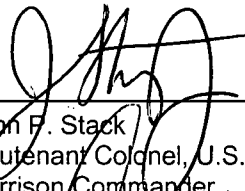
1.6 RECORD OF DECISION DATA CERTIFICATION CHECKLIST

The following information is included in the Decision Summary (Section 2.0) of this ROD (additional information can be found in the Administrative Record for this site).

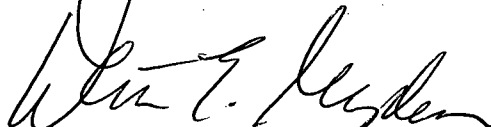
Criterion	Section	Page Number
Chemicals of Concern and Their Respective Concentrations	2.8.1.1 and Table 6	2-10 and 2-11
Current and Reasonably Anticipated Future Land Use Assumptions Used in Baseline Risk Assessment and ROD	2.7	2-9 and 2-10
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Criterion	Section	Page Number
Selected Remedy: Description, Estimated Capital, Annual Operation and Maintenance (O&M) and Total Present Worth Costs, Discount Rate, and the Number of Years Over Which the Remedy Cost Estimates are Projected	2.13	2-26 through 2-28
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1.7 AUTHORIZING SIGNATURE


 John F. Stack
 Lieutenant Colonel, U.S. Army
 Garrison Commander

25 FEB 09
 Date


 Walter E. Mugdan
 Director, Emergency and Remedial Response Division
 United States Environmental Protection Agency, Region 2

4/1/09
 Date

2.0 PART 2: DECISION SUMMARY

2.1 SITE NAME, LOCATION, AND DESCRIPTION

Picatinny Arsenal, located in Rockaway Township, NJ, is listed on USEPA's NPL. The CERCLIS identification number is NJ3210020704. The Army is the lead agency for the remedial actions at Area B of Picatinny Arsenal, and USEPA Region 2 is the lead regulatory agency with oversight responsibilities. Plans and activities are also being coordinated with the appropriate NJ State agencies, including the NJDEP. The funding for this action will be provided from the Environmental Restoration, Army (ER, A) account.

Picatinny is located approximately four miles north of the City of Dover in Rockaway Township, Morris County, NJ. The location of Picatinny is presented on **Figure 1**. Some of the nearby populous areas are Morristown, Morris Plains, Parsippany, Troy Hills, Randolph Township, and Sparta Township. The Picatinny Arsenal land area consists of 6,491 acres of improved and unimproved land. Picatinny Arsenal is situated in an elongated, classic, U-shaped glacial valley, trending northeast-southwest between Green Pond Mountain and Copperas Mountain on the northwest and an unnamed hill on the southeast. Most of the buildings and other facilities at Picatinny Arsenal are located on the narrow valley floor or on the slopes along the southeast side.

This ROD describes the preferred remedy to reduce human health and environmental risks associated with elevated concentrations of VOCs that are present in groundwater at Area B. Area B is approximately 28 acres in size and is located in the southwestern corner of Picatinny between Phipps Road and Green Pond Brook (GPB) (**Figure 1**). Area B includes two study sites, Site 20 (PICA-063) and Site 24 (PICA-066). Because Site 20 is completely contained within the boundaries of Site 24, these sites are considered one site (Site 20/24) for scoping and investigation purposes. Site 24 was used as a sanitary landfill and encompasses all of Area B. Site 20 was used for testing flares and signaling devices. Site 20 is currently active and is still used intermittently for the testing of pyrotechnics. Site 24 is currently inactive. **Figure 1** presents the location and layout of Area B on Picatinny.

The remedial action presented in this ROD was selected by the Army, in partnership with USEPA Region 2, in accordance with CERCLA, as amended by the SARA, and to the greatest extent possible, the NCP. NJDEP concurs with the selected remedy. The remedial action is funded by the Army and was selected in accordance with Army Regulation (AR) 200-1, Environmental Protection and Enhancement, as applicable.

2.2 SITE HISTORY AND ENFORCEMENT ACTIVITIES

2.2.1 Operational History

In 1940, Site 20 was undeveloped wetlands. By 1951, drainage ditches were present at the site. Trailer-sized structures, possibly for storage and observation of pyrotechnic displays, are evident in aerial photographs dated 1957. Activity at the site is evident in a 1966 photograph in which smoke is present along the western edge of the site. Sanitary waste, fly ash, ordnance, industrial waste, and sludge from the water treatment plant may have been dumped at Site 20/24 prior to 1972.

In 1940, Site 24 also was an undeveloped wetland area. Historical aerial photograph review indicates the slow expansion of the site from two small clearings to the current landfill area, approximately 28 acres. Drainage ditches are evident in 1951 aerial photos, along with an access road constructed diagonally across the site. Debris piles and filling activities are evident in 1961 aerial photos. Filling and disposal operations are apparent in 1963 and 1966 aerial photographs. Records on land filling activities are scarce; however, sanitary waste, fly ash, ordnance, industrial waste, and water treatment plant sludge were reportedly placed at the site until 1972.

2.2.2 Previous Remedial Actions In Area B

A remedial action was implemented within Area B between July 2002 and August 2003 to address contaminated soil at Site 20/24, under a USEPA-approved ROD, dated June 2002 (USEPA, 2002). Alternative No. 2: *Installation of a Vegetated Soil Cover and Continued Implementation of Land Use and Access Restrictions* was implemented in accordance with the ROD. The remedy addressed the soil COCs lead, polychlorinated biphenyls (PCBs), and 4, 4'-DDT, preventing access to direct contact and runoff to surface water. The soil cover spans an area of approximately 3.2 acres and is between 2 and 4 feet (ft)

thick. Prior to completing the cover, six excavations were completed around the perimeter of the approximate boundaries of the cover area to remove soil with PCB levels above the remedial goals (RGs). Excavated soil with PCB levels between 2 milligrams per kilogram (mg/kg) and 300 mg/kg was placed within the area to be covered. All soils with PCB concentrations above 300 mg/kg were disposed off-site. The edges of the soil cover within the 100 year flood plain were anchored with rip-rap to reduce the potential for washout of the contaminated materials beneath the soil cover. Following completion of the remedial activities, the cover was fertilized, mulched, and seeded, and the impacted wetlands were restored. Maintenance/ inspections of the cover are performed periodically to ensure the continued protectiveness of the cover. Additionally, because contamination remains on-site, land use and access restrictions are imposed as part of the remedial alternative. It has been determined through the results of a subsurface soil investigation that the contaminated soils within the cover do not act as a continuing source of groundwater contamination. A closure report for this remedial action was submitted in 2005 and approved by USEPA (Shaw, 2005a).

There has been no remedial action to date to address groundwater in Area B.

2.2.3 Previous Investigations

Some investigation of groundwater resources was initiated at Picatinny as early as 1958. However, most groundwater investigations have been conducted within the last twenty years. The locations of groundwater samples collected during these various studies at Area B are depicted on **Figure 2**. Groundwater investigations indicate that Area B groundwater, primarily within the unconfined aquifer, has been contaminated with VOCs, including cis-1, 2-dichloroethene (cis-1, 2-DCE), tetrachloroethene (PCE), trichloroethene (TCE), vinyl chloride (VC), and total xylenes. Additionally, metals including arsenic, iron, and manganese have been detected in Area B groundwater. However, it is believed that metals are naturally occurring constituents of the aquifer, and are present due to natural leaching of mineral constituents from the rock matrix through which the groundwater flows, rather than a result of anthropogenic (man-made) conditions.

2.2.4 Enforcement Activities

No formalized enforcement actions have been taken relative to Area B. Picatinny is working in cooperation with the USEPA and NJDEP to apply appropriate remedies that will preclude the necessity of formalized enforcement actions, such as Notices of Violation.

2.3 COMMUNITY PARTICIPATION

Picatinny has an active community participation program. The program includes a community relations plan, which is currently being updated, detailed public meetings, and an active Restoration Advisory Board (RAB). The Army funds a contractor to assist the RAB with technical issues under the Technical Assistance for Public Participation program. Area B groundwater has been the topic of presentations to the Picatinny Environmental RAB. The Army briefed the RAB on June 4, 1997 with the first update on groundwater investigations; July 29, 1999 with an update for Area B groundwater after completion of the investigations; January 27, 2000 on 20/24 Feasibility Study (for other environmental media); May 7, 2003 on the proposed remedial approach for Area B groundwater; April 1, 2004 on the proposed groundwater pilot study to evaluate the effectiveness of the biostimulant (reagent) Hydrogen Release Compound (HRC) in the treatment of VOCs in groundwater; June 15, 2004 with an update on the Area B Proposed Plan; and March 3, 2005 on the results of the HRC groundwater pilot study. Area B also was briefly discussed at the September 28, 2006 RAB meeting when the status of all sites was presented. RAB members have provided comments regarding the proposed remedial alternative. Copies of the Proposed Plan were given to the RAB's co-chair and to any RAB member who requested the document. The final Proposed Plan for Area B groundwater was completed in September 2005, and was released to the public at the information repositories listed below:

**Installation Restoration Program Office
Building 319 Picatinny, NJ 07806**

**Rockaway Township Library 61
Mount Hope Road
Rockaway Township, NJ 07866**

**Morris County Library
30 East Hanover Ave
Whippany, NJ 07981**

Multiple newspaper notifications were made to inform the public of the start of the Proposed Plan comment period, to solicit comments from the public, and to announce the public meeting. The notification was run in the New Jersey Star Ledger and the Daily Record on September 30, 2005. A public comment period was held from October 6, 2005 to November 7, 2005 during which comments from the public were received. A public meeting was held on October 6, 2005 to inform the public about the Selected Remedy for Area B groundwater and to seek public comments. At this meeting, representatives from the Army and USEPA were present to answer questions about the site and alternatives under consideration. The Army's responses to comments made at the public meeting are included in the Responsiveness Summary (Section 3.0) of this ROD.

2.4 SCOPE AND ROLE OF RESPONSE ACTION

As outlined in the IRP for Picatinny, the overall environmental cleanup goal is to protect human health and the environment. The remediation of Area B groundwater is part of a comprehensive process currently underway to meet the IRP goals for Picatinny.

This ROD addresses the selection of the remedial actions for groundwater at Area B.

The proposed remedial action for Area B groundwater is primarily targeted at the unconfined aquifer, which is impacted by low concentrations of VOCs dissolved in groundwater. Two pilot studies were conducted at Area B between October 2003 and January 2005 to determine if the addition of innocuous organic biostimulant substrates, such as HRC and Oxygen Release Compound (ORC) would accomplish chemical reduction of select VOCs in groundwater to levels below NJDEP Groundwater Quality Standards (NJGWQSs). The results of the pilot scale tests indicated that addition of such biostimulant substrates into the subsurface at Site 20/24 enhanced microbial activity and resulted in the chemical reduction of concentrations of select chlorinated ethenes and total xylenes in groundwater. Based on the results of the studies, it has been determined that in situ enhanced biodegradation will achieve the RAOs for Area B groundwater through use of a biostimulant substrate.

2.5 DOCUMENTATION OF SIGNIFICANT CHANGES

The Proposed Plan for Area B groundwater presented two selected remedial actions as the preferred alternatives for Area B groundwater. The two components included implementation of in situ enhanced bioremediation with HRC within a shortened/expedited timeframe for chlorinated ethenes, and implementation of in situ enhanced bioremediation with ORC for xylenes.

To assure achievement of the RAOs for the chlorinated VOCs, which is achievement of Applicable or Relevant and Appropriate Regulations [ARARs] in seven years (See Section 2.9 and Table 9), via the expedited in situ enhanced bioremediation Alternative 5B, the choice of reagent for subsurface injection to stimulate biodegradation of VOCs will be broadened beyond HRC. Other proven biostimulation substrates to be considered in lieu of HRC at the start of, or during, implementation of Alternative 5B include the following: molasses, cheese whey, and sodium lactate. Alternative substrates such as molasses will be considered because, at other sites across the country and within New Jersey, these substances have been demonstrated to have a higher subsurface mobility than HRC. This property facilitates the effectiveness of the injected substrate. Additionally, the choice of substrate delivery method(s) will be broadened beyond temporary direct push points in all or a portion of the impacted aquifer area. Additional delivery methods may include conventional permanent well arrays with either grid or linear traverse(s) perpendicular to groundwater flow. Well arrays facilitate repeat applications of reagent, where one portion of the aquifer may be more recalcitrant to cleanup than another. Further, delivery methods may be phased in over the planned remediation timeframe, as needed, to assure the delivery scheme maximizes reagent delivery and therefore expedited achievement of RAOs. The Remedial Design for Area B groundwater will specify in detail the reagent(s) and delivery method(s) selected to achieve the RAOs.

The selection of enhanced bioremediation to address xylenes was based on exceedance of the New Jersey Maximum Contaminant Level (NJ MCL) of 40 micrograms per liter (µg/L) for xylenes at the time the Area B FS was drafted. However, the NJ MCLs were updated in 2005 and the new NJ MCL for xylenes is 1,000 µg/L. The highest concentration of total xylenes detected in Area B groundwater when the FS was drafted

was 2,011 µg/L (in monitoring well MW 24-3). Since that time, the concentration of total xylenes in Area B groundwater has been demonstrated to be well below the recently promulgated standard in four rounds of sampling conducted subsequent to 1998 (**Table 1**). Therefore, implementation of enhanced bioremediation to address xylenes is not required in order to meet the remedial action objectives and has been removed as an objective of the selected remedial action.

2.6 SITE CHARACTERISTICS

2.6.1 Conceptual Site Model

A conceptual site model has been developed for the Area B groundwater plume in order to convey the salient processes affecting the introduction, movement, and distribution of contaminant mass at the site.

Chlorinated solvents (VOCs) and xylenes were introduced to the subsurface as a result of past waste storage and disposal practices associated with the landfill (Site 24). Results of multi-depth soil sampling in Area B indicate that no VOC sources remain in Site 20/24. Historically, contaminants were gradually transported to groundwater through infiltration and percolation mechanisms. Mobilization of contaminants in groundwater is believed to have occurred primarily through advection, dispersion, and diffusion mechanisms. Groundwater within the unconfined glacial aquifer discharges to surface water ponds and drainage ditches within the interior of Area B. Surface water quality standards have been exceeded only minimally at two locations within the interior of Area B. The remedial action for groundwater will address future discharges of groundwater to surface water by ensuring treatment (via biodegradation) prior to discharge. Groundwater in the unconfined and semi-confined aquifers eventually discharges to GPB. No COCs have been detected in GPB. The RI did not identify any at-risk ecological receptors in Area B or human health risk associated with applicable potential uses of GPB. **Figure 3** presents the conceptual site model for Area B groundwater.

2.6.2 Surface and Subsurface Features

The surface and subsurface features of Area B, such as topography, surface water hydrology, geology, and hydrogeology are described in Sections 2.6.3 through 2.6.5 below.

According to data contained in the Picatinny Geographic Information System (GIS), there are no archaeologically sensitive or potentially archaeologically sensitive areas within the boundaries of Area B. Cultural and historic data contained in the Picatinny GIS was primarily obtained from *Architectural Assessment of Historic Structures at Picatinny Arsenal, Morris County, New Jersey*, August 1999.

2.6.3 Topography/Surface Water Hydrology

The eastern two-thirds of Area B are flat; the western third of Area B is situated adjacent to a ridge that defines the western boundary of PTA and slopes gently to the east.

Most of Area B is approximately 690 to 700 ft above mean sea level (msl). Surface water runoff is controlled by a system of man-made drainage ditches (**Figure 2**). Surface water flow is influenced by both the system of drainage ditches at the site and the Landfill Pond. All drainage ditches lead into GPB, except for one ditch that leads directly into the Landfill Pond.

Geology and Soils

This section discusses the overall geology of Area B as well as the region between Area B and Route 15 to the southwest. The geology of Area B consists of the folded and faulted Leithsville Dolomite Formation overlain by flat-lying, Pleistocene glacial sediments. The Pleistocene glacial sediments are highly variable, but can be generally separated into three units that correspond to the three aquifers present in the unconsolidated sediments. The deepest unit consists primarily of sand and gravel, with lesser amounts of silt and clay. This unit corresponds to the lower semi-confined aquifer. The middle unit consists of sand, silt, and clay in varying proportions. This unit corresponds to the upper semi-confined aquifer. The shallowest unit consists of sand and silt with varying amounts of gravel. The glacial sediments are overlain in places with younger fluvial deposits and fine-grained overbank deposits. The youngest glacial deposits and the fluvial deposits correspond to the unconfined, or water table, aquifer. The bedrock and unconsolidated deposits are described in more detail in the paragraphs below. **Figure 2** shows the location of geologic cross-section A-A', which is oriented northwest to southeast (i.e., cross valley). This cross-section is shown on **Figure 4**.

As indicated in cross-section A-A', bedrock elevation drops steeply from approximately 650 ft msl [40 ft below ground surface (bgs) at the MW24-2 cluster] at the northwestern boundary to approximately 485 ft msl (204 ft bgs) at the MW24-4 cluster in the center of the valley. The bedrock surface at PTA dips gently from the northeast to the southwest along the strike of the valley; however, bedrock beneath Area B does not show an appreciable difference in elevation in this direction, exhibiting a bedrock elevation of 490 ft msl (209 ft bgs) at the SB3 cluster. Based on rock core samples collected at the SB3 monitoring well cluster at the southern boundary of the Arsenal, the Leithsville Formation consists of a light gray, micritic dolomite weathered to a yellow silty clay, with less weathered quartzitic dolomite layers. As is typical of a carbonate rock, large cavities ranging up to 20 ft in vertical extent are present and were encountered during monitoring well installation. These cavities are filled with silty fine sand and clay derived from weathering of the dolomite. Less weathered dolomite layers are highly fractured and exhibit stylolitic features perpendicular to bedding. The dominant fracture set observed in rock core samples is oriented vertically; secondary fractures do not show any regularity in orientation. Unweathered dolomite was not encountered in the two bedrock monitoring wells SB3-1A (completed at 360 ft bgs) and SB3-1B (completed at 336 ft bgs) located along the southern boundary of PTA. As indicated above, three sequences were recognized in the glacial sediments based on sediment grain size. In addition, a younger sequence of fluvial and overbank deposits is also present in Area B. The Pleistocene glacial sediments overlying bedrock in Area B increase in thickness from 40 ft at the western edge of the area to approximately 210 ft in the center of the valley. The lowest sequence of glacial sediments is a poorly sorted till consisting of sand and gravel, with variable amounts of clay, silt, cobbles, and boulders. The till is encountered at depths ranging from 40 to 157 ft bgs and ranges in thickness from 0 ft along the northwestern boundary of Area B, where it pinches out against bedrock, to 163 ft in the center of the valley.

This lower sequence is overlain by a fine-grained layer of silty sand, which ranges in thickness from approximately 25 ft. at monitoring well pair MW24-2A and MW24-2B, to 70 ft at monitoring well 20/24MW-2D. This fine-grained sequence is encountered at fairly uniform depths at Area B, approximately 10 to 20 ft bgs. One geotechnical sample was collected from this sequence during the ICF Kaiser Engineers (ICFKE) 1998 Additional Remedial Investigation (ARI). This sample was collected from drill cuttings composited from a depth of 80 to 82 ft bgs during the installation of 20/24MW-2D. This sample, classified as silt, contained 0% gravel, 5.3% sand, 62.0% silt, and 32.7% clay. Organic content was not tested in this sample.

The fine-grained sequence is overlain by a slightly coarser-grained sequence, which is the youngest glacial deposit and consists of poorly sorted sand and silt, with variable amounts of gravel and clay. Two geotechnical samples were collected from this sequence during the 1998 investigation conducted by ICFKE. One sample was collected from a depth of 12 ft bgs during the installation of monitoring well 20/24MW-1; the second sample was collected from a depth of 10 ft bgs during the installation of 20/24MW-2. These samples were classified as a silty sand with percent organic contents of 2.6 (20/24MW-1) and 2.1 (20/24MW-2). The sample from 20/24MW-1 was 13.1% gravel, 63.3% sand, 20.5% silt, and 3.1% clay. The sample from 20/24MW-2 was 2.2% gravel, 82.1% sand, 11.8% silt, and 3.9% clay.

The shallowest sequence present in Area B is a fluvial deposit consisting of sand, gravel, and silt. This unit has been reworked and altered in places through the land filling and drainage activities conducted in Area B. Two geotechnical samples were collected from these reworked fill sediments. One sample was collected from a depth of 10 ft bgs during the installation of monitoring well 20/24MW-1, while the second sample was collected from a depth of 4 ft bgs during the installation of 20/24MW-2. Both samples were classified as poorly graded sand with silt with percent organic contents of 13.4 (20/24MW-1) and 2.0 (20/24MW-2). The high organic content observed in the sample collected from 20/24MW-1 may be due to the fact that this monitoring well was installed in a relatively swampy area in the southern portion of Site 20/24 south of the Landfill Pond. Monitoring well 20/24MW-2 was installed in the central portion of the site west of the Landfill Pond. The sample from 20/24MW-1 was 14.1% gravel, 77.4% sand, 7.2% silt, and 1.3% clay. The sample from 20/24MW-2 was 1.5% gravel, 88.7% sand, 7.3% silt, and 2.5% clay.

2.6.4 Hydrogeology

A total of 16 monitoring wells have been installed in Area B as part of environmental investigations. **Figure 2** shows the approximate location of the monitoring wells in Area B.

Based on the geotechnical and slug test data collected during the Phase I RI and the Data Gap Investigation (DGI), Area B groundwater occurs in all four of the aquifers that comprise the total

groundwater system beneath Picatinny: the unconfined, glacially-derived sediment aquifer, the upper semi-confined glacial aquifer, the lower semi-confined glacial aquifer, and the bedrock aquifer.

The shallowest aquifer is an unconfined aquifer; the depth to the bottom of which ranges from 12 to 20 ft bgs in Area B and corresponds to the medium-grained, unconfined sequence of glacial sediments. The second aquifer, referred to as the upper semi-confined aquifer, is encountered at depths between 12 to 20 ft bgs and ranges in thickness from 25 ft at monitoring well pair MW24-2A and MW24-2B to 70 ft at monitoring well 20/24MW-2D. This aquifer corresponds to the intermediate fine-grained sequence. The lower semi-confined aquifer underlies the upper semi-confined aquifer and is the deepest aquifer in the unconsolidated glacial sediments. This aquifer pinches out against the bedrock at the northwestern side of Site 20/24 and increases in thickness towards GPB, where the depth to bedrock was determined to be 206 ft bgs during the installation of MW24-4B. The deepest aquifer is a bedrock aquifer which occurs in the Leithsville Formation under Area B. This formation is a weathered dolomite with karst features that have been filled with fine-grained sands and silts. Although no bedrock monitoring wells exist in Area B, monitoring wells SB3-1A and SB3-1B are located nearby at the southern boundary of PTA.

A total of ten monitoring wells in Area B are screened within the unconfined glacial aquifer. Depth to groundwater is fairly shallow, ranging from less than 1 ft bgs in the swampy, ponded areas of Site 24 to 3 ft bgs at the northwestern edge of Site 20/24. Local artesian conditions were encountered in MW-15 during the April/May 1994 groundwater sampling round. A series of drainage ditches have been cut through Area B which eventually discharge to GPB. Because the water table is very shallow, these ditches intersect the water table. These ditches may act as groundwater discharge points for the unconfined aquifer and influence shallow groundwater flow at Site 20/24. Groundwater flow appears to be somewhat controlled by the drainage ditches that bisect Site 20/24. In the central region of Site 20/24 (at greater distances from the ditches), groundwater flows southeasterly in the general direction of the Landfill Pond. Hydraulic gradients vary across the site, with higher values towards the northwest, on the flanks of the ridge, and lower values in the central flat portion of the site. In the area where chlorinated solvents are present, the hydraulic gradient is approximately 0.002 feet per foot (ft/ft). Based on an average hydraulic conductivity of 9.67 feet per day (ft/day), estimated from slug test data, which was discussed in the previous investigation reports, an assumed effective porosity value of 0.25, and an average hydraulic gradient of 0.002 ft/ft, the natural groundwater flow velocity in the unconfined glacial aquifer is estimated to average 0.077 ft/day across the entire site. In the area where chlorinated solvent contamination is present (see Section 2.6.7), the average hydraulic conductivity is 16 ft/day. This average was computed using the slug test results from monitoring wells 20/24MW-3 and MW-18. Using this hydraulic conductivity, a hydraulic gradient of 0.002 ft/ft, and an effective porosity of 0.25, the natural groundwater velocity in the unconfined aquifer where chlorinated solvents are present is 0.13 ft/day.

Three monitoring wells (MW24-2B, 20/24MW-1, and 20/24MW-2) are screened in the upper semi-confined glacial aquifer in Area B. Arsenal-wide groundwater flow maps indicate that groundwater in the upper semi-confined aquifer flows towards GPB. Hydraulic conductivities estimated from slug test data collected during the DGI for the upper semi-confined aquifer average 10.8 ft/day. The hydraulic gradient, based on the data points available in the upper semi-confined aquifer, is approximately 0.008 ft/ft. Using these values and an assumed effective porosity of 0.25, the natural groundwater velocity in the upper semi-confined aquifer is estimated to be 0.35 ft/day.

Two monitoring wells, MW24-4B and 20/24MW-2D, are screened within the lower semi-confined glacial aquifer in Area B. Depth to groundwater ranges between 1 ft bgs and 2 ft bgs in monitoring well 20/24MW-2 in the central part of Area B to 6 to 7 ft bgs near GPB in monitoring well MW24-4B. Arsenal-wide groundwater flow maps indicate that groundwater in the lower semi-confined glacial aquifer flows towards GPB from each side of the valley and then down-valley towards the southern boundary. The hydraulic gradient in the lower semi-confined aquifer in Area B is approximately 0.007 ft/ft. Based on an average hydraulic conductivity value of 48.5 ft/day, an assumed effective porosity value of 0.25, and an average hydraulic gradient of 0.007 ft/ft, the natural groundwater flow velocity is estimated to average 1.4 ft/day.

Monitoring well SB3-1B, located along the southern boundary of Picatinny, is the only monitoring well screened in the dolomitic bedrock aquifer. Arsenal-wide groundwater flow maps suggest that groundwater flows southwest (towards the terminal moraine) under an extremely gentle hydraulic gradient of 0.0005 ft/ft. Flow directions in the bedrock aquifer are not affected by the change in the course of GPB.

Three monitoring well pairs in the unconfined/upper semi-confined aquifers were used to estimate vertical gradients. Monitoring well pair MW24-2A and MW24-2B had a downward gradient of 0.017 ft/ft during both rounds of the Phase I RI sampling. According to the data collected in 1999 and 2000, the gradient has reversed and is now upward with a maximum upward gradient of 0.072 ft/ft. Vertical gradients were also calculated in the central part of Area B, where chlorinated solvents have been detected. The vertical gradient between monitoring well 20/24MW-3 (unconfined) and 20/24MW-2 (upper semi-confined aquifer) was 0.011 ft/ft in the downward direction. At monitoring well pair MW24-3 (unconfined) and 20/24MW-1 (upper semi-confined aquifer), where benzene, toluene, ethylbenzene, and xylene compounds have been detected in the unconfined aquifer, the gradient was upward for the two data sets used, with a maximum calculated vertical gradient of 0.004 ft/ft (May 1999 data).

One monitoring well pair (20/24MW-2 and 20/24MW-2D) was used to calculate the vertical gradient between the upper semi-confined and lower semi-confined aquifers. These monitoring wells are located in the central portion of Area B where chlorinated solvents have been detected in the groundwater and are screened in the upper semi-confined and lower semi-confined aquifers, respectively. The gradient was upward in 1999 and 2000, with a calculated value of 0.009 ft/ft for both data sets. In addition, one monitoring well pair (MW24-4A and MW24-4B) was used to calculate the vertical gradient between the unconfined and lower semi-confined aquifers. These monitoring wells are located near the southeast corner of Area B, adjacent to GPB. Vertical gradients between these two aquifers were calculated to be downward, with values ranging from 0.017 ft/ft (during the Phase I RI) to 0.040 ft/ft (during the most recent round of water levels).

2.6.5 Sampling Strategy

Several investigations of subsurface soil, groundwater, and surface water have been previously conducted at Area B. Based on data collected during previous investigations and during the 1999 DGI at Site 20/24, it appears that two areas of VOC contamination are present in groundwater as a result of former activities at the site. The first is a chlorinated solvent plume in the area of the pyrotechnic testing range. Groundwater in this plume contains elevated concentrations of TCE, 1, 2-dichloroethene (1, 2-DCE), and VC in the unconfined and upper semi-confined aquifers. This plume may have had several sources, but the main point of origination appears to be in the northwestern portion of Area B, near monitoring well 20/24MW-5. A second plume, containing PCE, was detected during the 1999 DGI in the upper semi-confined aquifer, trending northeast to southwest, between the metal testing stand near the boundary of Site 20 and the Landfill Pond. This plume likely is a result of a historical source separate from the main VOC plume. **Figure 2** presents the main areas/plumes of VOC contamination in Area B groundwater.

2.6.6 Nature and Extent of Groundwater Impact

This summary of the nature and extent of groundwater impact is based on several studies performed at the Site, largely: the RI, the ARI, and the DGI, which focused on Area B groundwater. Additionally, passive soil gas sampling conducted outside these studies, and independent work conducted by the U.S. Geological Survey, were used to understand the nature and extent of groundwater impact. The administrative record file for the site includes detailed information about individual investigations and sampling results summarized herein.

The three most comprehensive data sets (1994 Phase I RI; 1997/1998 ARI; and 1999 DGI) were used to spatially evaluate changes in the VOC plumes of highest concentration. Each round of data represents a time-referenced "snapshot" of the plume. **Figure 2** illustrates the main areas/plumes of VOCs in Area B groundwater and the locations of groundwater monitoring wells sampled during the previous investigations. Data sets and additional detail about the previous investigations, summarized in **Tables 2 through 4** and **Figures 5 through 10**, are available in the administrative record. As shown on these figures, the majority of VOC impact is in the unconfined aquifer in the northwestern portion of Area B.

The chlorinated VOCs historically detected at Area B have been found primarily in the unconfined aquifer. During the 1998 ARI, VC was detected at a concentration of 561 µg/L at monitoring well 20/24MW-2, which indicated that contamination had migrated to the upper semi-confined aquifer. The 1999 DGI was conducted to further delineate the vertical and lateral extent of VOC contamination in the unconfined and upper semi-confined aquifers. A total of eight VOCs were detected in groundwater samples collected during the DGI. Seven compounds, benzene, chlorobenzene, 1,1-DCE, cis-1,2-DCE, TCE, VC, and xylenes (total), were detected at concentrations greater than their respective levels of concern (LOCs). In addition, 14

VOCs were detected in the direct push groundwater samples; however, only four of these compounds (cis-1, 2-DCE, methylene chloride, PCE, and VC) exceeded their respective LOCs. However, the Area B Groundwater FS concluded that exceedances of benzene, chlorobenzene, and 1, 1-DCE do not appear to be associated with a plume. Detections of benzene and chlorobenzene are isolated, while detections of 1, 1-DCE appear to be sporadic and are likely to be the results of the degradation of more highly chlorinated VOCs. The extent of contamination of the COCs in Area B groundwater is discussed individually in the following paragraphs.

PCE Contamination. PCE was detected during the investigations in the upper semi-confined aquifer during the 1999 DGI. The detections of PCE above the LOCs range from 1.4 to 73 µg/L. The maximum concentration of PCE was detected at a depth of 40 to 44 ft bgs within the upper semi-confined aquifer. The FS concluded that PCE contamination originated from separate spills because the detections were observed at the downgradient area of the location (northwestern and central portions of Area B) where historical detections of other chlorinated VOCs were observed. **Figures 5 and 7** present the lateral and vertical extent of the PCE plume, respectively.

TCE Contamination. The results of the previous investigations have indicated that TCE contamination predominantly occurs in the unconfined aquifer and the upper semi-confined aquifer. TCE was not identified in samples collected from the lower semi-confined aquifer. TCE was observed at its highest level in the unconfined aquifer in direct push sample 20/24HP-5. TCE was detected at a concentration of 34.4 µg/L, which exceeds the LOC of 1 µg/L. Monitoring well 20/24MW-2 yielded the highest TCE levels in the upper semi-confined aquifer. TCE concentrations in 20/24MW-2 ranged from 18 µg/L to 26.2 µg/L during the three rounds of groundwater monitoring conducted between 1998 and 1999. **Figures 6 and 7** show the lateral and vertical extent of TCE contamination, respectively.

Cis-1, 2-DCE Contamination. Cis-1, 2-DCE contamination was observed in both the unconfined and upper semi-confined aquifers. The DGI results indicated the highest cis-1, 2-DCE concentration of 390 µg/L was found in the upper semi-confined aquifer; cis-1, 2-DCE ranged from 46 to 250 µg/L in the unconfined aquifer. Previous analyses (1999 quarterly monitoring events) reported a concentration of 600 µg/L in one monitoring well (20/24MW-2). The LOC for cis-1, 2-DCE is 10 µg/L. **Figures 8 and 10** show the lateral and vertical extent of cis-1, 2-DCE contamination, respectively.

VC Contamination. The extent of VC contamination encompasses an area within the unconfined and upper semi-confined aquifers. However, the majority of the contamination occurs in the unconfined aquifer beneath monitoring well 20/24MW-3. The maximum concentrations of VC were observed at 1,520 µg/L in the unconfined aquifer and at 760 µg/L in the upper semi-confined aquifer, exceeding its LOC of 1 µg/L. **Figures 9 and 10** show the lateral and vertical extent of VC contamination in the unconfined and upper semi-confined aquifers, respectively.

Enhanced bioremediation with HRC was proposed as part of Remedial Alternatives 5B and 8 for reducing concentrations of VC, cis-1,2-DCE, TCE, and PCE in Area B groundwater. A pilot study was conducted at Area B between October 2003 and January 2005 to determine if addition of HRC would accomplish reduction of select VOCs in groundwater to levels below NJDEP Groundwater Quality Standards (GWQS). HRC was injected at seven points in Area B in November 2003 via direct-push technology at depths ranging from 3 to 16 ft bgs. The locations of the points were selected based on the distribution of chlorinated ethenes in the unconfined aquifer. **Figure 11** shows the locations of the HRC injection points and monitoring wells installed as part of this pilot study. Injection of HRC also was proposed in the vicinity of newly-installed up-gradient monitoring wells 20/24MW-9, 20/24MW-10, and 20/24MW-11 as part of the Final Work Plan Area B Site 20/24 Groundwater HRC/ORC Pilot Study (Shaw, 2003). However, the injection points were not installed in this area based on the analytical results of the pre-injection monitoring.

The analytical results of the post-injection monitoring indicated that concentrations of chlorinated ethenes (cis-1,2-DCE and VC) in groundwater decreased steadily over time as a result of the injected biostimulant. The most notable decline of cis-1,2-DCE and VC was observed in 20/24MW-8. The lowest concentrations of cis-1,2-DCE and VC in this well were 2.1 µg/L and 4.2 µg/L, respectively. Ethene concentrations continually increased in each of the three wells for the first year of sampling and then gradually decreased during the last rounds of monitoring. The highest ethene concentrations in each of the monitoring wells were observed over the three month period from February 2004 to May 2004. Injection of HRC was also proposed in the vicinity of the newly-installed up-gradient monitoring wells 20/24MW-9, 20/24MW-10, and 20/24MW-11 as part of the Final Work Plan, Area B Site 20/24 Groundwater HRC/ORC Pilot Study (Shaw 2003). The range

of concentrations for cis-1,2-DCE, VC, and ethene observed prior to and following HRC injection are summarized graphically on **Figure 12**.

Geochemical data collected from 20/24MW-6, 20/24MW-7, and 20/24MW-8 indicated the aquifer exhibits reducing conditions due to the presence of methane and hydrogen. The analytical results further indicate that the addition of the HRC facilitated reductive dechlorination to ethene. Based on the results of this pilot study, HRC, or a similar substrate, is capable of reducing concentrations of chlorinated ethenes in Area B to NJGWQSS within seven years.

Surface water samples have been collected from the Landfill Pond, GPB, and drainage ditches as part of historical sampling to investigate the interconnectivity of surface water and groundwater. **Table 5** presents a summary of historical surface water sampling results and illustrates the frequency and range of detection for all analytes, as well as exceedances of New Jersey Surface Water Quality Standards.

2.6.7 Area B Groundwater Plume Characteristics

The most prominent feature of Area B groundwater is a chlorinated solvent plume. This plume was created when solvents were introduced into subsurface materials through historic waste disposal practices.

The Army has identified four chemicals in Area B groundwater that pose the greatest potential risk to human health. The characteristics of the four COCs that have been identified in Area B groundwater are presented below:

- **Tetrachloroethene (PCE)** is a halogenated organic compound historically used as a solvent and degreaser in many industries. Exposure to this compound has been associated with deleterious health effects in humans.
- **Trichloroethene (TCE)** is a halogenated organic compound historically used as a solvent and degreaser in many industries. Exposure to this compound has been associated with deleterious health effects in humans. Based on laboratory studies, TCE is considered a probable human carcinogen.
- **Cis-1, 2-Dichloroethene (cis-1, 2-DCE)** is a halogenated organic compound formed through the breakdown of TCE by microorganisms. Exposure to this compound has been associated with deleterious health effects in humans.
- **Vinyl Chloride (VC)** is a halogenated organic compound formed through breakdown of cis-1, 2-DCE and 1, 1-dichloroethene. Exposure to this compound has been associated with deleterious health effects in humans. VC is a known human carcinogen.

2.6.8 Fate and Transport of PCE and TCE

The fate and transport characteristics of the contaminants that reside in the plume are vital aspects of the chemical compounds that affect their behavior, ability to mobilize, rate of degradation, and probability of human, biotic, or ecological exposure. The important processes that may influence the fate of TCE and PCE include physical transport processes, such as advection, diffusion, volatilization, and adsorption, and natural degradation processes, such as chemical reactions and biodegradation. Further details on the fate and transport of COCs in Area B groundwater are discussed in the Final Area B Groundwater Feasibility Study (IT, 2002).

2.7 CURRENT AND POTENTIAL FUTURE LAND USES AND DESIGNATION OF AREA B

The Picatinny master planning land use designation for the majority of the land within Area B is research, development, and testing. The portions of Area B that are still forested wetlands are designated as wetland on the land use map. The site is used primarily for the testing of pyrotechnic flares, but is also designated as a safe haven parking area and is periodically used for hunting purposes. The Safe Haven Plan allows for temporary parking of explosives-laden vehicles and is large enough to accommodate two 18-wheel trucks. The site is located within Hunting Area 18. Hunting Area 18 is open to all game and hunting activities, which take place between early October and February. In addition to the current uses of this site, the Army has installed a small weather station. The weather station is situated on a 25-foot by 25-foot concrete pad.

The State of New Jersey has designated all groundwater within the state as a drinking water source. However, Picatinny has a centralized water distribution system and it has no current or future plans for the

use of Area B Groundwater for any purpose. Area B is within an NJDEP approved Classification Exception Area (CEA) as described in a letter dated July 29, 2002 to the NJDEP. The CEA was established for all groundwater beneath Picatinny in both the bedrock aquifers, and unconsolidated sediment aquifers (which comprise the lower semi-confined, upper semi-confined and unconfined aquifers as discussed in this document). Thus, the CEA addresses all aquifers and COCs for Area B groundwater. Upon establishment of a CEA due to exceedances of the NJGWQS, NJDEP identifies the region within the CEA as a well restriction area (WRA). As long as the CEA is in place, NJDEP is obligated to restrict or require the restriction of potable groundwater use, and may prohibit the installation and pumping of wells within this area.

The future land use of Area B is anticipated to remain unchanged from current land use activities. Area B will continue to be used for research, development, and testing activities by the Army.

2.8 SUMMARY OF SITE RISKS

This section presents the results of the Area B human health and ecological risk assessments that were conducted for the Phase I RI by Dames & Moore. The risk assessments were designed to evaluate the potential impact to human health and the environment. It should be noted that data collected during the ARI and the DGI were not included in this assessment as the data collected during these investigations were similar to the Phase I RI and would not significantly change the risk assessment.

The risk assessments summarized below were performed at the request of the USEPA. Given that all aquifers beneath Area B are within the CEA, which has an associated mandatory well restriction institutional control, human exposure and subsequent risk to untreated groundwater was determined only for the following future potential receptors: site workers, combined adult/child residents and individual child residents. The groundwater COC that presented the greatest risk to these receptors was VC. Protection of these future potential receptors from an unacceptable risk is the basis for implementing a remedial action for groundwater at Area B.

2.8.1 Human Health Risk Assessment

To determine whether remedial action is warranted, USEPA requires a baseline human health risk assessment (HHRA) be conducted for each site. The baseline risk assessment is an evaluation of cancer risks and non-cancer hazards of constituents of potential concern (COPCs) associated with a site if no remedial action were taken. It provides the basis for taking action and identifies the contaminants and exposure pathways that need to be addressed by the remedial action. This section summarizes the results of the baseline risk assessment for this site. As part of the baseline HHRA, estimates of exceeded cancer risks and non-cancer health hazards are quantified for potential receptor populations and exposure scenarios.

Currently, USEPA guidelines for generally acceptable exposures are excess individual lifetime carcinogenic risks in the range of 1×10^{-6} (one in one million) and 1×10^{-4} (one in ten thousand). Exceedances of this acceptable range may trigger a requirement for remedial action.

Potential non-carcinogenic effects are evaluated by comparing the calculated exposure intake to the chemical-specific reference dose for each COC. This ratio of exposure to toxicity is called the hazard quotient (HQ). HQs greater than 1 are indicative of potential adverse health effects. The hazard index (HI) is the sum of all HQs for all COPCs that affect the same target organ, or act through the same mechanism of action within a media or across all media, of a reasonably maximum exposed individual. In general, HIs that are less than 1 are not likely to be associated with adverse health effects.

The Phase I RI HHRA was prepared to evaluate the probability and magnitude of adverse effects on human health associated with actual or potential exposure to groundwater containing COPCs that were selected for evaluation. The HHRA was based on groundwater data collected during the Phase I RI.

2.8.1.1 Identification of Contaminants of Concern

This section presents a summary of the COC selection that was performed as part of the Area B Groundwater FS (IT, 2002). A determination of COCs was also performed for the Phase I HHRA (Dames and Moore, 1998) in accordance with the Risk Assessment Guidance for Superfund. The COC selection performed for the FS included an evaluation of the HHRA COCs.

COCs were identified for Area B groundwater based on exceedances of groundwater standards and contaminant distribution indicative of a contaminant plume. Inorganic contaminants that were detected sporadically or exhibited random distribution were removed from COC consideration. The five COCs identified in Area B groundwater during the FS stage were cis-1, 2-DCE, PCE, TCE, VC, and xylenes (total). As explained in Section 2.5, xylene is no longer a COC. **Table 6** presents the maximum concentrations of COCs detected in Area B groundwater compared to the groundwater standards.

2.8.1.2 Exposure Assessment

Figure 3 presents a conceptual site model of environmental transport media and principal exposure routes for Area B groundwater.

The potential pathways through which individuals may be exposed to COCs were discussed in detail within the Phase I RI HHRA. Probable exposure pathways were then selected for quantitative evaluation in the HHRA. Using the site-specific data obtained from the field samples, chemical concentrations were computed for the points of potential exposure associated with each pathway selected for quantitative evaluation. Assumptions were made for the magnitude, frequency, and duration of exposure for each pathway, and potential exposures (intakes) were then quantified. Detailed evaluations for the incidental ingestion and dermal absorption of sediment can be found in the Phase I RI HHRA.

For Area B groundwater, hypothetical future exposures to groundwater for workers, and for combined adult/child residents, and child residents alone were evaluated for ingestion, inhalation, and skin contact risks. The risks were calculated for the unconfined aquifer and semi-confined aquifers separately. The potential receptors and pathways through which individuals could be exposed to groundwater contamination included the following:

- Future ingestion of groundwater used for drinking water by Picatinny workers;
- Future ingestion of groundwater used for drinking water by combined child/adult residents;
- Future ingestion of groundwater used for drinking water by on-site child residents;
- Future dermal absorption of chemicals in groundwater while bathing by on-site child residents;
- Future inhalation of VOCs in groundwater while showering by combined child/adult residents; and,
- Future inhalation of VOCs in groundwater while showering by on-site child resident

It should be noted that groundwater contact through any of these pathways is not expected to occur because of the facility-wide CEA and land use controls that will be implemented as a result of this ROD.

2.8.1.3 Toxicity Assessment

The potential toxicity of chemicals to humans was presented and the chemical-specific toxicity criteria were compiled for each COC within the Phase I risk assessment. Specifically, the toxicity criteria used in the quantitative assessment were obtained from USEPA's Integrated Risk Information System, the Health Effects Assessment Summary Tables, and the National Center for Environmental Assessment.

2.8.1.4 Risk Characterization

For carcinogens, risks are generally expressed as the incremental probability that an individual will develop cancer over a lifetime as a result of exposure to the carcinogen. Excess lifetime cancer risk is calculated from the following equation:

$$\text{Risk} = \text{CDI} \times \text{SF}$$

where: risk = a unitless probability (e.g., 2×10^{-5}) of the likelihood that an individual will develop cancer

CDI = chronic daily intake averaged over 70 years (mg/kg-day)

SF = slope factor, expressed as (mg/kg-day)⁻¹

These risks are probabilities that usually are expressed in scientific notation (e.g., 1×10^{-6}). An excess lifetime cancer risk of 1×10^{-6} indicates that an individual experiencing the reasonable maximum exposure

estimate has a 1 in 1,000,000 chance of developing cancer as a result of site-related exposure. This is referred to as an "excess lifetime cancer risk" because it would be in addition to the risks of cancer individuals face from other causes such as smoking or exposure to too much sun. The NCP generally identifies cancer risks in the range of 10^{-4} to 10^{-6} as protective for site-related exposures for NPL sites.

The potential for non-carcinogenic effects is evaluated by comparing an exposure level over a specified time period (e.g., lifetime) with a reference dose (RfD) derived for a similar exposure period. An RfD represents a level that an individual may be exposed to that is not expected to cause any deleterious effect. The ratio of exposure to toxicity is called an HQ. An $HQ < 1$ indicates that a receptor's dose of a single contaminant is less than the RfD, and that toxic noncarcinogenic effects from that chemical are unlikely. The HI is generated by adding the HQs for all chemicals of concern that affect the same target organ (e.g., liver) or that act through the same mechanism of action within a medium or across all media to which a given individual may reasonably be exposed. An $HI < 1$ indicates that, based on the sum of all HQs from different contaminants and exposure routes, toxic noncarcinogenic effects from all contaminants are unlikely. An $HI > 1$ indicates that site-related exposures may present a risk to human health. The HQ is calculated as follows:

Non-cancer $HQ = CDI/RfD$

Where: CDI = chronic daily intake
RfD = reference dose.

CDI and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or short-term).

2.8.1.5 Area B Groundwater

The unconfined and upper/lower semi-confined groundwater strata were evaluated independently. All samples collected during the Phase I RI for Area B groundwater (all three sampling rounds) were used in the HHRA to assess risks associated with groundwater exposures. Refer to **Table 7** for a summary of the HHRA and **Table 6** for a summary of the COC selection process carried out in the FS.

Exposures to HHRA COPCs in groundwater from the unconfined aquifer were associated with total cancer risks of 2×10^{-4} for workers, 1×10^{-3} for combined adult/child residents, and 4×10^{-4} for child residents. Although five VOCs were selected as COPCs in this groundwater aquifer, the largest single risk driver (i.e., chemicals that contributed most significantly to the elevated risks for each of the receptors) was VC. The HIs for all pathways combined were 9 for workers, 3 for adult/child residents, and 50 for child residents. The largest single contributor to the elevated HIs was iron. Although iron was included in the risk assessment, it was not selected as a COC in the FS because it is not believed to be associated with site activities. Rock formations and soils at Picatinny are rich in iron; so much so, that iron has been mined historically from the surrounding area. During the RI, iron was detected in groundwater from every well sampled, including the up-gradient Area B well. These sampling results are indicative of the ubiquitous, natural occurrence of iron in Picatinny groundwater. Exposures to HHRA COPCs in groundwater from the semi-confined aquifers (the HHRA did not differentiate between the upper and lower semi-confined aquifers) were associated with total cancer risks of 1×10^{-4} for workers, 6×10^{-4} for adult/child residents, and 2×10^{-4} for child residents. Compounds responsible for the majority of calculated risk were arsenic, beryllium, and 2, 3, 7, 8-TCDD. The pattern of arsenic detections is not indicative of a release from the site. Detections of arsenic above the maximum contaminant level (MCL) were sporadic and included the well up-gradient of Area B. Detections of beryllium and 2, 3, 7, 8-TCDD were also sporadic and limited. Beryllium was detected at three locations randomly distributed across the site during four of the 23 sampling events (Dames and Moore, 1998) and was not detected in any of the 12 existing monitoring wells sampled during the subsequent 1998 investigation. Similarly, 2,3,7,8-TCDD was only detected once in lower semi-confined aquifer during July 1994 sampling event and was not detected in any of the subsequent groundwater sampling events. Contaminants that were detected sporadically or exhibited random distribution were removed from COC consideration. No VOCs were selected as HHRA COPCs in the semi-confined aquifer groundwater grouping. The HIs were 0.9 for workers, 4 for adult/child residents, and 5 for child residents. The chemicals that accounted for the elevated HIs included arsenic, manganese, and iron. Although iron, manganese, and arsenic were included in the risk assessment, they were not selected as COCs in the FS because there is no reason to believe they are associated with site activities. As stated above, rock formations and soils at Picatinny are rich in iron and in other, associated metals such as arsenic and manganese. As is the case with iron, manganese

is also detected in nearly all samples of Picatinny groundwater. In the semi-confined aquifers in Area B, iron and manganese were detected in every well, including the up-gradient well.

The risk assessment for Area B groundwater indicated exposure to groundwater resulted in unacceptable risk due to VOC contamination. The principal VOC contributing to the elevated risk (the pathway with the greatest risk) is VC in the unconfined aquifer, for the ingestion pathway (the land use scenario under which such an exposure would occur is not reasonably anticipated, given the planned future use of Area B and the direction of groundwater flow to the southeast toward the Landfill Pond). No VOCs contributed significantly to HIs exceeding the threshold value of 1.0 for the groundwater ingestion pathway.

2.8.1.6 Ecological Risk Assessment

There are no potential ecological risks associated with Area B groundwater. The Phase I RI baseline ecological risk assessment (BERA) considered the potential for ecological risk from VOCs in surface water. No VOCs were identified as ecological chemicals of potential concern (ecoCOPCs) for further evaluation because these chemicals are not persistent in surface water or surface soils within the vadose zone and will not bioaccumulate. Thus, there are no VOC concerns in surface water from an ecological risk perspective. As a result, the selection of a remedial alternative for Area B was not impacted by ecological risk.

2.9 REMEDIAL ACTION OBJECTIVES (RAOs)

RAOs are based on human health and environmental factors that must be considered in the evaluation of response actions. Such objectives are developed based on criteria outlined in Section 121 of CERCLA and in the NCP.

Attainment of the RAOs will enhance protection of human health and the environment. The final selected remedial action will attain site cleanup levels for Area B groundwater that will be protective to the measure of all identified Applicable, or Relevant and Appropriate Regulations (ARARs) for currently identified at-risk receptors at all respective potential points of exposure. The RAOs for each COC at Area B are as follows:

- Prevent exposure to Area B groundwater COCs at levels above ARARs (see Table 9);
- Protect uncontaminated groundwater for designated uses;
- Minimize migration of contaminants to adjacent groundwater and surface water; and
- Restore contaminated groundwater to comply with its use designation.

2.10 DESCRIPTION OF ALTERNATIVES

Area B groundwater has undergone an RI/FS in accordance with the CERCLA process. The RI phase is the mechanism for collecting data to characterize the site and assess potential human health and ecological risk. The RI phase is followed by the FS phase, which involves the development, screening, and detailed evaluation of remedial alternatives.

Technology types and process options appropriate for the COCs were identified and screened based on effectiveness, implementability, and cost. The retained technologies and process options were developed into remedial alternatives. The remedial alternatives are:

- Alternative 1: No Action;
- Alternative 2: Limited Action with Monitored Natural Attenuation (MNA);
- Alternative 3: In Situ Chemical Oxidation;
- Alternative 4: In Situ Ferox Iron Slurry Injection with Pneumatic Fracturing (PF) and MNA;
- Alternative 5A: In Situ Enhanced Bioremediation;
- Alternative 5B: Expedited In Situ Enhanced Bioremediation; and,
- Alternative 9: Configured Groundwater Extraction Wells for Contaminant Mass Removal.

Limited action is defined as those minimally necessary institutional or engineering controls required to meet, alone or in combination with other remedies, the area-specific RAOs. An example of an institutional control would be the CEA WRA. Engineering controls are generally physical barriers designed to limit exposure to site contamination or to contain contaminated groundwater. Limited engineering controls were not considered as part of Alternative 2 Limited Action with MNA as this alternative was developed to provide minimal actions that may be taken to limit exposure to the contaminated media.

In situ enhanced bioremediation is defined as addition of a suitable biostimulant directly into groundwater that promotes microbial growth and decay of the groundwater COCs to harmless degradation products at an increased rate over what ambient aquifer conditions promote alone (without any substrate). A pilot test using HRC was successful in demonstrating the viability of anaerobic microbial stimulants to remediate Area B groundwater. Accelerating in situ enhanced bioremediation through the use of other biostimulants, such as molasses, cheese whey and sodium lactate, will be considered, and the selected amendment will be specified in the final design of the remedial system. In particular, molasses has been shown to have increased mobility for broader, quicker distribution, expanding the radius of influence (ROI) of a given groundwater injection point, for an overall reduction in the scope of the delivery system, the frequency of substrate delivery, and the overall time required for remediation.

Alternatives 6, 7, and 8 were evaluated as part of the FS to address xylenes in groundwater. Because concentrations of xylenes in Area B groundwater no longer exceed the NJGWQS for these compounds, these alternatives were not carried forward as a component of this ROD. It should also be noted that costs for Alternative 9 include some costs associated with the treatment of xylenes.

All active restoration alternatives will require implementation of existing institutional restrictions and land use controls (LUCs) as remediation components.

All of the listed alternatives were carried forward to the detailed analysis, where each alternative was evaluated against the nine criteria set in Section 300.430(e) of the NCP. Descriptions of the seven remedial alternatives retained for detailed analysis are presented in the following sections.

2.10.1 Alternative 1: No Action

Estimated Capital Cost: \$0

Estimated O&M Cost: \$0

Estimated Present Worth Cost: 0

CERCLA and the NCP require that a No Action alternative be evaluated at every site to establish a baseline for the comparison of other remedial alternatives. Under this alternative, no remedial action would take place.

2.10.2 Alternative 2: Limited Action with MNA

Estimated Capital Cost: \$58,500

Estimated O&M Cost: \$562,800

Estimated Present Worth Cost: \$621,300

Alternative 2, the Limited Action with MNA alternative, has been developed to provide minimal actions that may be taken to limit public exposure to the contaminated media, while demonstrating reduction of contamination by natural processes. Alternative 2 involves no active treatment processes to reduce the toxicity, mobility or volume of contaminants.

The following components are incorporated into Alternative 2:

Institutional Restrictions: Institutional restrictions involve controlling access to contaminated areas by implementing administrative policies. Administrative policies of interest include restricting future property uses within contaminated areas and restricting groundwater use. One such institutional restriction that has already been implemented at Picatinny is the site wide CEA for groundwater and associated WRA, as discussed previously.

The Army is responsible for implementing, maintaining, reporting on, and enforcing the LUCs. LUCs will be maintained until the concentrations of hazardous substances in the groundwater are at such levels to allow for unrestricted use and exposure. A LUC remedial design will be prepared as the land use component of the remedial design. Within 90 days of ROD signature, the Army will prepare and submit to USEPA for review and approval a LUC remedial design that shall contain implementation and maintenance actions, including periodic inspections. The following LUC objectives will be met by the implementation of LUCs:

- Prohibition of groundwater use until such time as contaminant levels do not exceed site cleanup levels (assured by CEA and associated WRA);
- Maintain integrity of monitoring wells necessary to implement the remedy; and,
- Prohibit excavation without safeguards (e.g., measures to prevent exposure to contaminated groundwater and vapor) in all areas below the water table in the plume footprint.

LUCs will be maintained and 5-year reviews will be performed for Area B until contaminant levels are shown to allow for unrestricted use. When the concentrations of COCs fall below the remedial goals, groundwater monitoring will be terminated in accordance with an approved exit strategy and documented in the next 5-year review.

Although the Army may later transfer these procedural responsibilities to another party by contract, property transfer agreement, or through other means, the Army shall retain ultimate responsibility for remedy integrity.

Institutional restrictions described under this alternative would be incorporated into Alternatives 3, 4, 5A, 5B, and 9.

Long-Term Groundwater Monitoring (LTM) and Surface Water Monitoring (including Natural Attenuation Parameters and Demonstration of MNA): The demonstration of plume remediation via MNA will be performed through the collection, analysis and interpretation of field and laboratory data consistent with EPA's Office of Solid Waste and Emergency Response (OSWER) Policy Directive 9200.4-17, CERCLA guidance and N.J.A.C. 7:26E-6.3(d) and (e). Data will be used to evaluate and predict changes in the nature and extent of plume chemistry over time relative to groundwater standards and potential receptors identified in the risk assessment, until RAOs are achieved and LTM can cease, or another RA is required. Specifically, data will be used to 1) revise, as needed, the conceptual site model (CSM) developed in the RI, 2) verify or revise current estimated contaminant degradation rates, and 3) revise, as needed, the detailed, site-specific groundwater fate and transport assessment developed as a part of the Remedial Design (RD) for determination of receptor impact or RAO achievement.

Natural degradation of the Area B plume will be monitored from a network of groundwater wells and surface water locations representative of the former source area, the dissolved plumes in the unconfined, upper semi-confined and lower semi-confined, unconsolidated aquifers, and potential receptors. The RD will identify the final monitoring network based on the plume dimensions and the anticipated fate and migration of the plume over time from the groundwater fate and transport assessment. This assessment will consist of, at a minimum, an evaluation of empirical data, and as applicable, an analytical or numerical groundwater flow, and fate and transport model. The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria.

The frequency of sampling and the analytical suite of parameters will be defined in the RD, with the following schedule established herein as the minimum basis for the RD: quarterly for the first two years following Remedy-In-Place (RIP), semi-annually thereafter until the CERCLA mandated five year review, then every five years for the remainder of the initial 30-year planning horizon identified in the RD until achievement of RAOs and Remedy Complete (RC), which is currently estimated at 100 years. The analytical suite of parameters to be monitored and reported for each sampling event will be those COCs identified in the FS: PCE, TCE, cis-1, 2-DCE and VC. To document that aquifer conditions are conducive to long-term reductive dehalogenation of the COCs, biogeochemical indicator parameters will be analyzed at a reduced frequency relative to VOC COCs, and from a reduced subset of monitoring locations. The following schedule will be followed for biogeochemical parameter monitoring: quarterly for the first year; annually for years two through five and completion of the first five year review; then every five years for the remainder of

the projected duration of the MNA remedy. The RD will determine the biogeochemical monitoring network and analytical suite, which will consist of, at a minimum: total organic carbon (TOC), nitrate, total and dissolved iron, sulfate and the following field measured parameters: pH, DO, ORP, temperature, and specific conductance.

Public Education: Public awareness of the hazards present at the site will continue to be maintained through public meetings and posting of signs, as needed.

Emergency Provisions: In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, would be identified and updated.

As previously discussed, buried munitions have been unearthed at this site. The discoveries included potentially live ordnance items as well as bulk uncased high explosives (HE). While it is not anticipated that this remedial alternative will require the installation of additional groundwater monitoring wells, UXO avoidance will be required if new wells are installed.

2.10.3 Alternative 3: In Situ Chemical Oxidation and MNA

Estimated Capital Cost: \$2,046,800

Estimated O&M Cost: \$518,200

Estimated Present Worth Cost: \$2,565,000

Alternative 3 proposes use of liquid permanganate to chemically oxidize chlorinated VOCs (primarily VC) in the areas of in situ remediation to a threshold VC concentration of 20 ug/l, after which MNA can proceed to attainment of RAOs/ARARs. Permanganate is a strong oxidant with a long history of safe use in drinking water, wastewater, and chemical manufacturing industries. Chemical oxidation using permanganate in soil and groundwater can be achieved by the passive addition of the oxidant into the treatment zone. The permanganate reacts with all reduced species in the aquifer, including chlorinated compounds. Permanganate in the form of KMnO_4 would be added to the Area B chlorinated VOC plume. The permanganate disperses through the aquifer through groundwater flow and gravitation effects.

One concern with this alternative is the release of unreacted KMnO_4 to surface water. However, due to the high metal levels in soil at Picatinny and the contaminants found within the Area B plume, it is unlikely that permanganate would reach a discharge point. If permanganate were to reach the interface with ponds or surface drainage ditches, organic material in the sediments would likely react with the permanganate immediately, preventing any transport downstream. The possibility of non-point source discharge will be investigated and compliance with any substantive requirement for surface water discharge will be ensured. Loading of permanganate to the groundwater will be adjusted such that breakthrough to the surface water is prevented.

The following technologies and actions are incorporated into this alternative:

Injection of Potassium Permanganate: In situ chemical oxidation facilitates oxidation processes within the subsurface by direct injection into the Area B groundwater chlorinated VOC plume. The RD will detail all aspects of the final remediation program. Potassium permanganate injection, well installation and wetlands disturbance will be detailed in the RD, which will include the substantive requirements of NJDEP for these activities. Direct-push injection wells will be installed in the areas of remediation to inject KMnO_4 into the subsurface. Carus Chemical, distributor of the KMnO_4 , has designed a chemical delivery system that will be available for rental at the site. The permanganate will be shipped to the site in Cycle Bins consisting of 3300 pounds of permanganate each. With a rented forklift, the Cycle Bin is placed above a mix tank, where the permanganate is diluted in water. The three percent solution is then pumped to a storage tank. From the storage tank, the solution is pumped through the injection manifold and into each manifold leg and injection point. Modular manifold systems have been constructed for other permanganate application projects for 30 simultaneous injections. The system consists of a pre-manifold header with a totalizing flow meter, valving, and temperature and pressure gauges. From here the solution is conveyed to the polyvinyl chloride (PVC) pressure hoses for distribution. Each manifold line consists of PVC pressure tubing, a digital flow meter, and pressure gauge.

Three 2-inch diameter wells will be installed to monitor the chemical quality of groundwater downgradient of the injection points as well as within the areas of remediation.

Technical and construction oversight would be required prior to and during the installation of the *in situ* chemical oxidation system. Typically, a more comprehensive data review and a site visit and meeting will be conducted by the design group. In addition, while the *in situ* chemical oxidation system is being installed (approximately 12 weeks), a field engineer, quality control officer, and health and safety manager would be required to be on-site.

Additional costs for the *in situ* chemical oxidation system would include the performance of a bench scale and pilot-scale test to determine KMnO_4 requirements, pumping duration, etc. Also included in the cost of this alternative are insurance, bonds, and a contingency factor.

Institutional Restrictions: Since contamination would remain on-site while treatment and MNA are taking place, LUCs, as described under Alternative 2, would be required as part of this alternative.

Long-Term Groundwater and Surface Water Monitoring (including Natural Attenuation Parameters and Demonstration of MNA): MNA will be used to remediate the mass of contaminants remaining in the areas of remediation once the VC concentration in the targeted areas is reduced to 20 $\mu\text{g/L}$. In addition, MNA will be used to demonstrate chemical reduction in the remaining portions of the plume. It is estimated from the degradation constant calculated for the site that the groundwater quality will be in compliance with ARARs after 30 years. Following the *in situ* chemical oxidation duration of 2 years, the total duration for remediation is estimated to be 32 years. The target cleanup level for VC, and the injection and remediation timeframes were calculated based on the results of four different methodologies and literature reviews used to evaluate and estimate the degradation rates for select VOCs (VC, TCE, and cis-1, 2-DCE) at the site. The data from each method were examined and compared in order to determine the most accurate method considering the amount of available data. Detailed descriptions of each method and additional information regarding the process in which target cleanup levels and remediation timeframes were determined can be found in Section 7.0 of the *Final Area B Groundwater Feasibility Study* (IT, 2002).

The demonstration of plume remediation via active chemical oxidation and then MNA will be performed through the collection, analysis and interpretation of field and laboratory data consistent with EPA's Office of Solid Waste and Emergency Response (OSWER) Policy Directive 9200.4-17, CERCLA guidance and N.J.A.C. 7:26E-6.3(d) and (e). Data will be used to evaluate and predict changes in the nature and extent of plume chemistry over time relative to groundwater standards and potential receptors identified in the risk assessment until RAOs are achieved and LTM can cease. Specifically, data will be used to 1) revise, as needed, the CSM developed in the RI, 2) verify or revise current estimated contaminant degradation rates, and 3) revise, as needed, the detailed, site-specific groundwater fate and transport assessment developed as a part of the RD for determination of receptor impact or RAO achievement.

The chemical oxidation program and natural degradation of the remainder of the Area B plume will be monitored from a network of groundwater wells and surface water locations representative of the former source area, the dissolved plumes in the unconfined, upper semi-confined and lower semi-confined, unconsolidated aquifers, and potential receptors. The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria. The RD will identify the final monitoring network based on the current plume dimensions, and the anticipated fate and migration of the plume over time from the groundwater fate and transport assessment. This assessment will consist of, at a minimum, an evaluation of empirical data and as applicable, an analytical or numerical groundwater flow, and a fate and transport model.

The frequency of sampling and the analytical suite of parameters will be defined in the RD, with the following schedule established herein as the minimum basis for the RD: quarterly for the first year following the initial chemical oxidation treatment of the groundwater to monitor performance of the chemical oxidation program and degradation of the plume to the 20 $\mu\text{g/l}$ VC threshold; quarterly for years two and three to verify the aquifer will support natural biodegradation of the remainder of the plume; then annually for years four and five until the first five year review; then every five years for the remainder of the 30-year planning horizon, until achievement of RAOs, which is currently estimated at 30 years. The analytical suite of parameters to be monitored and reported for each sampling event will be those COCs identified in the FS: PCE, TCE, cis-1, 2-DCE and VC. To document aquifer conditions are stable to continue to promote long-

term reductive dehalogenation of the COCs, biogeochemical indicator parameters will be analyzed on a reduced frequency relative to VOC COCs and from a reduced subset of monitoring locations. The following schedule will be followed for biogeochemical parameter monitoring: quarterly for the first year following the attainment of the 20 ug/l threshold (year 2); annually for years two through five and completion of the first five year review; then every five until RC at year 30. The RD will determine the biogeochemical monitoring network and analytical suite, which will consist of, at a minimum: Total Organic Carbon (TOC), nitrate, total and dissolved iron, sulfate and the following field measured parameters: pH, DO, ORP, temperature, and specific conductance.

Public Education: Public awareness of the hazards present at the site will be achieved through public meetings and posting of signs, as needed.

Emergency Provisions: In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, would be identified and updated.

As previously discussed, buried munitions have been unearthed at this site. The discoveries included potentially live ordnance items as well as bulk uncased HE. This remedial alternative will require the installation of new groundwater monitoring wells and direct push injection points. These intrusive activities will require UXO avoidance techniques.

2.10.4 Alternative 4: In Situ Ferox Iron Slurry Injection with Pneumatic Fracturing (PF) and MNA

Estimated Capital Cost: \$2,354,900

Estimated O&M Cost: \$504,400

Estimated Present Worth Cost: \$2,859,300

Alternative 4 involves the implementation of *in situ* iron slurry injection (trade name Ferox), which is a patented technology owned by ARS Technologies. Implementation of the Ferox technology, through the injection of zero-valent iron (ZVI) powder into the aquifer matrix with nitrogen gas, will reduce chlorinated VOCs in the unconfined and upper semi-confined aquifers. The system will be comprised of 208 and 35 direct-push injections in the unconfined and upper semi-confined aquifers, respectively, preceded by pneumatic fracturing (PF) of the aquifer matrix. Groundwater monitoring wells will be installed to monitor system effectiveness. The Ferox technology will be used to remediate contamination in the targeted areas. The remediation system will consist of iron slurry, nitrogen gas, transfer pumps, and injection points. The remainder of the plume will be treated by MNA.

The following technologies and actions are incorporated into this alternative:

Injection of Iron Powder Slurry and Nitrogen Gas This action will include activities such as PF of the aquifer matrix, installation of approximately 243 direct-push injection wells, and injection of iron-slurry with nitrogen gas (carrier gas) into the subsurface. Iron slurry injection, well installation and wetlands disturbance will be detailed in the RD, which will include the substantive requirements of NJDEP for these activities. The *in situ* iron slurry injection system itself will require an engineering design.

Institutional Restrictions: Since contamination would remain on-site while treatment and MNA are taking place, LUCs, as described under Alternative 2, would be required as part of this alternative.

Performance Monitoring: Following the initial Ferox injection and RIP, performance of the Ferox treatment program will consist of soil and groundwater sampling. Ten soil borings will be advanced at the beginning of the monitoring period to assess the distribution of the iron powder and chloride. Groundwater samples will be collected from six wells in the unconfined aquifer and five wells in the upper semi-confined aquifer quarterly for eight quarters. The groundwater samples will be analyzed for VOCs and target analyte list (TAL) metals. A change in redox state may mobilize some metals that were previously immobile by allowing them to become soluble. Analyzing for TAL metals will monitor any changes.

Long-Term Groundwater and Surface Water Monitoring (including Natural Attenuation Parameters and Demonstration of MNA): MNA will be used to remediate the mass of contaminants remaining in the areas of remediation once the VC concentration in the targeted areas is reduced to 20 µg/L. It is estimated from the degradation constant calculated for the site that the groundwater concentration will be in compliance with

ARARs after approximately 30 years. Following the reduction in concentration by in situ iron slurry injection (not to exceed 2 years), the total duration for remediation is estimated to be 32 years. The target cleanup level for VC and the injection and remediation timeframes were calculated based on the results of four different methodologies and literature reviews used to evaluate and estimate the degradation rates for select VOCs (TCE, cis-1,2-DCE, and VC) at the site. The data from each method was examined and compared in order to determine which method was most accurate considering the amount of available data. Detailed descriptions of each method and additional information regarding the process in which target cleanup levels and remediation timeframes were determined can be referenced in Section 7.0 of the *Final Area B Groundwater Feasibility Study* (IT, 2002).

The demonstration of plume remediation via MNA will be performed through the collection, analysis and interpretation of field and laboratory data consistent with EPA's Office of Solid Waste and Emergency Response (OSWER) Policy Directive 9200.4-17, CERCLA guidance and N.J.A.C. 7:26E-6.3(d) and (e). Data will be used to evaluate and predict changes in the nature and extent of plume chemistry over time relative to groundwater standards and potential receptors identified in the risk assessment until RAOs are achieved and LTM can cease, or another RA is required. Specifically, data will be used to 1) revise, as needed, the conceptual site model (CSM) developed in the RI, 2) verify or revise current estimated contaminant degradation rates, and 3) revise, as needed, the detailed, site-specific groundwater fate and transport assessment developed as a part of the Remedial Design (RD) for determination of receptor impact or RAO achievement.

Natural degradation of the remainder of the Area B plume will be monitored from a network of groundwater wells and surface water locations representative of the former source area, the dissolved plumes in the unconfined, upper semi-confined and lower semi-confined, unconsolidated aquifers, and potential receptors. The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria. The RD will identify the final monitoring network based on the current plume dimensions, and the anticipated fate and migration of the plume over time from the groundwater fate and transport assessment. This assessment, at a minimum, will consist of an evaluation of empirical data, and as applicable, an analytical or numerical groundwater flow, and fate and transport model.

Public Education: Public awareness of the hazards present at the site will be achieved through public meetings and posting of signs, as required.

Emergency Provisions: In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, would be identified and updated.

As previously discussed, buried munitions have been unearthed at this site. The discoveries included potentially live ordnance items as well as bulk uncased HE. This remedial alternative will require the installation of new groundwater monitoring wells and direct push injection points. These intrusive activities will require UXO avoidance techniques.

2.10.5 Alternative 5A: In Situ Enhanced Bioremediation and MNA

Estimated Capital Cost: \$702,500

Estimated O&M Cost : \$596,400

Estimated Present Worth Cost: \$1,298,900

Alternative 5A originally proposed the injection of HRC, a proprietary chemical that accelerates the growth and activity of anaerobic reductive dechlorinating microbes in the aquifer by providing slow-release hydrogen. The technology originated out of the fertilizer industry, in which slow-release oxygen fertilizers were developed for water-saturated environments. HRC has been used at a variety of sites to treat chlorinated VOCs since its introduction as an innovative remedial alternative product in 1997. Since its introduction, HRC injection has gained wide acceptance as one of the ways to enhance bioremediation. Additionally, as stated in Section 2.5, it is now recognized that Area B RAOs can be achieved using any one of a variety of substances that act as biostimulants for the reductive dechlorination process. These substances include substrates such as molasses, cheese whey and sodium lactate, the effectiveness of which have been proven at a variety of contaminated sites. Additionally, such substances have been shown

to be potentially capable of achieving RAOs in a reduced timeframe. Biostimulant injection, well installation and wetlands disturbance will be detailed in the RD, which will include the substantive requirements of NJDEP for these activities.

The following technologies and actions are incorporated into this alternative:

Injection of Biostimulant: The biostimulant will be introduced into the aquifer either by direct-push technology (DPT) or through constructed injection wells. The FS identified that approximately 358 direct push injection points would be required to reduce the VC concentration to 20 µg/L, the concentration at which MNA will be viable as a polishing step.

Institutional Restrictions: Since contamination would remain on-site while treatment and MNA are taking place, LUCs, as described under Alternative 2, would be required as part of this alternative.

Performance Monitoring: To demonstrate the effectiveness of the biostimulant and distribution system on the bioremediation of chlorinated VOCs, particularly VC, performance monitoring of groundwater will be performed. Groundwater samples will be collected from monitoring wells from within the treated areas, and upgradient and downgradient regions. Six wells in the unconfined aquifer and five wells in the upper semi-confined aquifer will be sampled quarterly for the first two years. These groundwater samples will be analyzed for VOCs (each event) and biodegradation indicator parameters, listed below in the LTM/MNA section (each event for the first year, then semi-annually during year two).

Long-Term Groundwater and Surface Water Monitoring (including Natural Attenuation Parameters and Demonstration of MNA): MNA will be used to remediate the mass of contaminants remaining in the areas of remediation once the VC concentration in the targeted areas is reduced to 20 µg/L. In addition, MNA will be used to demonstrate chemical reduction in the remaining portions of the plume. It is estimated from the degradation constant calculated for the site that the groundwater quality will be in compliance with ARARs after 30 years. From the initial biostimulant injection through maintenance injections (not to exceed 2 years) and MNA, the total duration for remediation is estimated to be 32 years. This estimate is conservative, particularly with the chemical treatment technologies, and will serve as a maximum time required for further contaminant reduction. It may also eliminate the need for additional injections.

The demonstration of plume remediation via MNA will be performed through the collection, analysis and interpretation of field and laboratory data consistent with EPA's Office of Solid Waste and Emergency Response (OSWER) Policy Directive 9200.4-17, CERCLA guidance and N.J.A.C. 7:26E-6.3(d) and (e). Data will be used to evaluate and predict changes in the nature and extent of plume chemistry over time relative to groundwater ARARs and potential receptors identified in the risk assessment until RAOs are achieved and LTM can cease, or another RA is required. Specifically, data will be used to 1) revise, as needed, the CSM developed in the RI, 2) verify or revise current estimated contaminant degradation rates, and 3) revise, as needed, the detailed, site-specific groundwater fate and transport assessment developed as a part of the RD for determination of receptor impact or RAO achievement.

Natural degradation of the remainder of the Area B plume will be monitored from a network of groundwater wells and surface water locations representative of the former source area, the dissolved plumes in the unconfined, upper semi-confined and lower semi-confined, unconsolidated aquifers and potential receptors. The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria. The RD will identify the final monitoring network based on the plume dimensions, and the anticipated fate and migration of the plume over time from the groundwater fate and transport assessment. This assessment, at a minimum, will consist of an evaluation of empirical data, and as applicable, an analytical or numerical groundwater flow, fate and transport model.

The frequency of sampling and the analytical suite of parameters will be defined in the RD, with the following schedule established herein as the minimum basis for the RD: quarterly for the first two years following attainment of the 20 µg/l threshold concentration (years 3 and 4), semi-annually for year five and completion of the first five year review, then every five years for the remainder of the 30-year planning horizon, until achievement of RAOs, which is currently estimated at 30 years. The analytical suite of parameters to be monitored and reported for each sampling event will be those COCs identified in the FS: PCE, TCE, cis-1, 2-DCE and VC. To document aquifer conditions are stable to continue to promote long-term reductive dehalogenation of the COCs, biogeochemical indicator parameters will be analyzed on a reduced frequency relative to VOC COCs and from a reduced subset of monitoring locations. The following

schedule will be followed for biogeochemical parameter monitoring: quarterly for the first year following the attainment of the 20 ug/l threshold (year 3); annually for years four and five; then every five years through the 25-year planning horizon, plus one 5-year revision until RC at year 30. The RD will determine the biogeochemical monitoring network and analytical suite, which will consist of, at a minimum: total organic carbon (TOC), nitrate, total and dissolved iron, sulfate and the following field measured parameters: pH, DO, ORP, temperature, and specific conductance.

Public Education: Public awareness of the hazards present at the site will be achieved through public meetings and posting of signs, as necessary.

Emergency Provisions: In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, would be identified and updated.

As previously discussed, buried munitions have been unearthed at this site. The discoveries included potentially live ordnance items as well as bulk uncased HE. This remedial alternative will require the installation of new groundwater monitoring wells and direct push injection points. These intrusive activities will require UXO avoidance techniques.

2.10.6 Alternative 5B: Expedited In Situ Enhanced Bioremediation

Estimated Capital Cost: \$1,143,600

Estimated O&M Cost: \$404,600

Estimated Present Worth Cost: \$1,548,200

Alternative 5B involves implementation of in situ enhanced bioremediation within a shortened/expedited timeframe. Alternative 5B will achieve compliance with groundwater ARARs within seven years. Therefore, MNA as a polishing step will not be required. The FS identified that the expedited restoration timeframe will be achieved through an increased number of biostimulant injections and expanded treatment area. To achieve the 7-year restoration time, the entire groundwater plume will be actively treated. To assure Alternative 5B is as robust as possible in terms of meeting the 7-year cleanup time frame, the addition of other similar reagents, such as molasses, cheese whey or sodium lactate is included for consideration in the final Remedial Design, as identified in Section 2.5.

The following technologies and actions are incorporated into this alternative:

Injection of Biostimulant: The RD will detail the final remedial system. Biostimulant will be delivered to groundwater via direct push points, or constructed injection wells, or a combination of both, in one or more phases to assure RAOs are achieved within the 7-year timeframe. The FS identified that approximately 500 biostimulant injection points will be required. On an equivalent basis, injection via wells may require up to six (6) linear traverses with eleven (11) wells each in the unconfined aquifer, oriented perpendicular to groundwater flow and spaced hydraulically downgradient based on groundwater velocities, and up to three (3) traverses of eleven (11) wells each in the upper semi-confined aquifer, with the same orientation and aquifer specific spacing. Barrier lines of wells may be installed incrementally, beginning with the most upgradient traverse relative to the highest dissolved phase concentrations, followed by installation of successive lines hydraulically downgradient as the resolution of COC mass reduction at one line is realized. The RD will detail the final optimum injection network, arrived at through use of an area-specific groundwater flow and COC fate numerical model. Details of biostimulant injection, well installation and wetlands disturbance will be detailed in the RD, which will include the substantive requirements of NJDEP for these activities.

In comparison to Alternative 5A, the major changes in capital costs include an increase in biostimulant, an increase in DPT points or an exchange of points with conventional wells, and oversight for the expanded treatment area. The major change in O&M costs includes the elimination of MNA (sampling, analysis, modeling, and reporting).

Institutional Restrictions: Since contamination would remain on-site while treatment is taking place, LUCs, as described under Alternative 2, would be required as part of this alternative.

Performance Groundwater and Surface Water Monitoring: The demonstration of plume remediation via expedited in situ enhanced biodegradation will be performed through the collection, analysis and

interpretation of field and laboratory data as detailed in the final RD. Data will be used to evaluate and predict changes in the nature and extent of plume chemistry over time relative to groundwater ARARs and potential receptors identified in the risk assessment until RAOs are achieved on or before the 7-year RC target. Specifically, data will be used to 1) revise, as needed, the CSM developed in the RI, 2) verify or revise current estimated contaminant degradation rates, 3) design and implement additional focused biostimulant injections, and 4) revise, as needed, the detailed, site-specific groundwater fate and transport assessment developed as a part of the RD for determination of receptor impact or RAO achievement

Degradation of the Area B plume will be monitored from a network of groundwater well and surface water locations representative of the former source area, the dissolved plumes in the unconfined, upper semi-confined and lower semi-confined, unconsolidated aquifers, and potential receptors. The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria. The RD will identify the final monitoring network based on the current plume dimensions, and the anticipated fate and migration of the plume over time from the groundwater fate and transport assessment. This assessment, at a minimum, will consist of an evaluation of empirical data, and as applicable, an analytical or numerical groundwater flow, and fate and transport model.

The frequency of sampling and the analytical suite of parameters will be defined in the RD, with the following schedule established herein as the minimum basis for the RD: quarterly for the two years following RIP during the period of more frequent recurring biostimulant injections; semi-annually years three through five, then annually years six and seven. The analytical suite of parameters to be monitored and reported for each sampling event will be those COCs identified in the FS: PCE, TCE, cis-1,2-DCE and VC. To document aquifer conditions have been suitably modified to promote expedited in situ enhanced biodegradation of the COCs, biogeochemical indicator parameters will be analyzed on a reduced frequency relative to VOC COCs and from a reduced subset of monitoring locations. The following schedule will be followed for biogeochemical parameter monitoring: quarterly for the first year; then semi-annually the second and third years, then annually years four through seven. The RD will determine the biogeochemical monitoring network and analytical suite, which will consist of, at a minimum: total organic carbon (TOC), nitrate, total and dissolved iron, sulfate and the following field measured parameters: pH, DO, ORP, temperature, and specific conductance.

Public Education: Public awareness of the hazards present at the site will be achieved through public meetings and posting of signs, as necessary.

Emergency Provisions: In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, would be identified and updated.

As previously discussed, buried munitions have been unearthed at this site. The discoveries included potentially live ordnance items as well as bulk uncased HE. This remedial alternative will require the installation of new groundwater monitoring wells and direct push injection points. These intrusive activities will require UXO avoidance techniques.

2.10.7 Alternative 9: Configured Groundwater Extraction Wells for Contaminant Mass Removal and MNA

Estimated Capital Cost: \$899,200

Estimated O&M Cost: \$2,730,500

Estimated Present Worth Cost: \$3,629,700

The mass removal-configured extraction wells will be able to reduce groundwater contamination to the VC concentration threshold of 20 ug/l by extracting groundwater from the targeted areas of remediation and treating it above ground at a treatment plant before natural biodegradation will treat the remainder of the plume. The FS estimated 18 years to reach the VC threshold, with 30 years required to assure attainment of chemical-specific ARARs at receptor points of exposure. The system will be comprised of extraction pumps, a collection tank, an air stripper, and a carbon adsorption system. This alternative will utilize a newly constructed treatment plant located in close proximity to the groundwater plume.

This alternative will require the following actions:

- *Design and construction of a groundwater treatment plant*, including Air Stripping/Vapor Phase Carbon Treatment and Aqueous Phase Carbon Absorption Polishing.
- *Installation of five extraction wells*: Two wells will be installed in the unconfined aquifer and two installed in the upper semi-confined aquifer of Region 1, and one in the unconfined aquifer of Region 2.
- *Discharge to Surface Water (GPB)*

Institutional Restrictions: Since contamination would remain on-site while treatment and MNA are taking place, LUCs, as described under Alternative 2, would be required as part of this alternative.

Long-Term Groundwater and Surface Water Monitoring (including Natural Attenuation Parameters and Demonstration of MNA): The demonstration of plume remediation via groundwater extraction and then MNA will be performed through the collection, analysis and interpretation of field and laboratory data consistent with EPA's Office of Solid Waste and Emergency Response (OSWER) Policy Directive 9200.4-17, CERCLA guidance and N.J.A.C. 7:26E-6.3(d) and (e). Data will be used to evaluate and predict changes in the nature and extent of plume chemistry over time relative to groundwater ARARs and potential receptors identified in the risk assessment, until RAOs are achieved and LTM can cease, or another RA is required. Specifically, data will be used to 1) revise, as needed, the CSM developed in the RI, 2) verify or revise current estimated contaminant degradation rates, and 3) revise, as needed, the detailed, site-specific groundwater fate and transport assessment developed as a part of the RD for determination of receptor impact or RAO achievement.

Aquifer cleanup via groundwater extraction and natural degradation of the remainder of the Area B plume will be monitored from a network of groundwater wells and surface water locations representative of the former source area, the dissolved plumes in the unconfined, upper semi-confined and lower semi-confined, unconsolidated aquifers, and potential receptors. The groundwater action will include monitoring of the surface water until the groundwater action results in COC concentrations in the Landfill Pond that are below the New Jersey Surface Water Quality Criteria. The RD will identify the final monitoring network based on the current plume dimensions, and the anticipated fate and migration of the plume over time from the groundwater fate and transport assessment, which will consist of, at a minimum, an evaluation of empirical data and, as applicable, an analytical or numerical groundwater flow, and fate and transport model.

The frequency of sampling and the analytical suite of parameters will be defined in the RD, with the following schedule established herein as the minimum basis for the RD: Annually through attainment of the 20 ug/l VC concentration threshold; quarterly for the first two years following attainment of the 20 ug/l threshold concentration (years 19 and 20); annually for years 21 and 22, then every five years until ARARs are attained. The analytical suite of parameters to be monitored and reported for each sampling event will be those COCs identified in the FS: PCE, TCE, cis-1, 2-DCE and VC. To document aquifer conditions are stable to continue to promote long-term reductive dehalogenation of the COCs, biogeochemical indicator parameters will be analyzed on a reduced frequency relative to VOC COCs and from a reduced subset of monitoring locations. The following schedule will be followed for biogeochemical parameter monitoring: quarterly for the first year following the attainment of the 20 ug/l threshold (year 19); annually for years 20 and 21; then every five years until RC. The RD will determine the biogeochemical monitoring network and analytical suite, which will consist of, at a minimum: TOC, nitrate, total and dissolved iron, sulfate and the following field measured parameters: pH, DO, ORP, temperature, and specific conductance.

Public Education: Public awareness of the hazards present at the site will be achieved through public meetings and posting of signs, as required.

Emergency Provisions: In the event of an unexpected deterioration of site conditions resulting in an increased threat to public health and the environment, emergency measures are outlined to allow prompt attention to the problem. Existing emergency provisions, if any, would be identified and updated.

As previously discussed, buried munitions have been unearthed at this site. The discoveries included potentially live ordnance items as well as bulk uncased HE. This remedial alternative will require the installation of new groundwater monitoring wells and direct push injection points. These intrusive activities will require UXO avoidance techniques.

2.11 COMPARATIVE ANALYSIS OF ALTERNATIVES

The Army and USEPA selected the preferred alternative by evaluating each of the alternatives against the nine criteria established by USEPA. These criteria are described below.

The advantages and disadvantages of each of the alternatives were compared using the nine CERCLA evaluation criteria established by USEPA in Section 300.430(e) of the NCP. The detailed comparative analysis of all the alternatives is provided in the FS for Area B; a summary of this comparison is provided in the following text.

2.11.1 Threshold Criteria (must be met)

2.11.1.1 Overall Protection of Human Health and the Environment

This criterion addresses whether each alternative provides for protection of human health and the environment by eliminating, reducing, or controlling exposure to human or environmental receptors. Alternatives 3, 4, 5A, 5B and 9 would provide protection to human health and the environment. Alternatives 3, 4, 5A, 5B, and 9 would reduce contaminant concentrations to ARARs through treatment, and LUCs would remain in effect during the treatment period. Alternative 2 affords human health protection only through the maintenance and implementation of LUCs, primarily the groundwater use restrictions, with the additional benefit of ambient aquifer-driven COC biodegradation. Alternative 1 is least protective, having no use restrictions to afford short-term protection, relying solely on ambient aquifer driven biodegradation.

2.11.1.2 Compliance with ARARs

This criterion addresses whether a remedy would meet all of the ARARs related to the hazardous substances at the site and the circumstances of their release. Alternative 1, No Action, was considered as the CERCLA required baseline remedy, which may ultimately meet ARARs as a result of ambient aquifer driven biodegradation. However, monitoring and measuring the progress of biodegradation processes is not part of the alternative. Alternatives 2, 3, 4, 5A, 5B and 9 are expected to meet ARARs as a result of ambient aquifer conditions or engineered/enhanced conditions.

2.11.2 Primary Balancing Criteria (identifies major trade-offs among alternatives)

2.11.2.1 Long-term Effectiveness and Permanence

This criterion addresses the remaining risk and the ability to protect human health and the environment over time once cleanup levels have been met.

Alternatives 2, 3, 4, 5A, 5B and 9 all reduce contaminant mass while achieving ARARs, thereby permanently restoring groundwater quality and designated uses of groundwater.

2.11.2.2 Short-term Effectiveness

This criterion addresses impacts to the community and site workers during cleanup including the amount of time it takes to complete the action, or in other words, the amount of time that groundwater remains impacted above ARARs.

Alternatives 1 and 2 do not pose any hazards to workers in the short term. However, neither of these alternatives is effective in the short term, because neither remedy materially improves groundwater quality on a short-term basis.

Of the engineered remedial alternatives, Alternative 3, in situ chemical oxidation, poses the greatest hazards due to the potential contact with contaminated soils and groundwater while injection is taking place. In addition, contact with the permanganate solution is a worker hazard. Alternatives 4, 5A, and 5B also involve injection of material into the aquifer, which pose risks associated with the contaminated media and the injection solution. In terms of short-term effectiveness, all of these remedies materially improve groundwater quality within weeks to months following implementation, thereby reducing the time that groundwater remains impacted above ARARs and remains a risk to workers and potential off-site groundwater users. Alternative 5B has the highest potential for short-term effectiveness as it incorporates an engineered remedy for the entire plume.

Alternative 9 involves the greatest amount of construction, which may cause risk to workers. Although its time frame to reach ARARs is comparable to the other treatment remedies, it has limited effectiveness of improving groundwater quality over the short term.

2.11.2.3 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion addresses the anticipated performance of treatment systems in achieving significant reductions in toxicity, mobility, or volume of hazardous substances as a principal threat at the site.

The remedies that best satisfy this criterion are Alternatives 3, 4, 5A, and 5B, each having a high degree of success in permanently reducing contaminant mass and reducing VOC concentrations to ARARs, but at variable rates and with variation in length of time that the plume remains potentially mobile. There is no active treatment provided under Alternatives 1 and 2; however the RI/FS has shown that ambient aquifer conditions will drive natural biodegradation of dissolved contaminant mass, but at slower rates than under active treatment. The plume remains more mobile under these alternatives when compared to the other alternatives. Alternatives 3 and 4 provide treatment by oxidizing (in the case of Alternative 3) or reducing (in the case of Alternative 4) the contaminants in the groundwater and contaminants sorbed to aquifer sediments, which significantly reduces plume mobility relative to the above alternatives. Alternatives 5A and 5B provide treatment that relies on the enhancement of biological processes as opposed to a chemical reaction that relies merely on contact with the contaminant. Alternatives 3, 4, and 5A by design will only incorporate engineered remedies for a portion of the plume, with MNA treating the remainder of the plume, thereby extending the time frame for plume mobility. Alternative 5B best meets this criterion, achieving mass and toxicity reduction throughout the entire plume while immobilizing the plume in the shortest time frame.

Alternative 9 has a reduced chance of efficiently and effectively reducing contaminant mass from Area B groundwater because pump and treat technology is not as efficient as other engineered in-situ remedies at treating the contaminant mass in the immobile pore space within the aquifer; although Alternative 9 best restricts plume mobility via hydraulic control. Further, although contaminant mass is removed from the aquifer, it is not degraded to innocuous end products, but simply transferred to another form, thereby achieving no reduction in COC toxicity.

2.11.2.4 Implementability

This criterion addresses the technical and administrative feasibility of an alternative from design through construction and operation. Factors such as the availability of materials and services, administrative feasibility, and coordination with other governmental agencies are also considered.

All alternatives are readily implementable; however, approvals from other agencies would be difficult to obtain for Alternative 1. Alternative 2 requires minimal resources, principally capital and maintenance costs associated with a monitoring well network, the majority of which is already present. Alternatives 3, 4, 5A and 5B require extensive material handling, but little construction. Extensive construction is required for Alternative 9 since it requires trenching, pipe fitting and treatment plant construction, operation and maintenance. Permitting for all engineered remedies is reduced as a result of permit equivalents.

2.11.2.5 Cost

This criterion compares the difference in costs, including capital, operation, and maintenance costs.

Present worth costs were calculated with a discount rate of seven percent for each alternative. **Table 8** shows the estimated present worth and capital cost for each alternative for Area B groundwater.

There are no costs associated with Alternative 1. Alternative 2 is the most cost effective of the alternatives. Alternative 5A, Enhanced Bioremediation with HRC, has the lowest capital cost (\$702,500) and lowest O&M cost (\$596,400), making it the most cost effective of the active alternatives. Alternatives 3 and 4 have similar capital and O&M costs. Alternative 5B, Expedited Enhanced Bioremediation with HRC, has a significantly lower cost than Alternatives 3 and 4 and a slightly higher cost than Alternative 5A. The present worth cost of Alternative 9 is substantially higher than that of any other alternative (\$3,629,700).

2.11.3 Modifying Criteria (formally evaluated after the comment period)

2.11.3.1 State Acceptance

This criterion evaluates whether the State agrees with, opposes, or has no comment on the preferred alternative. This criterion is evaluated formally when comments on the Proposed Plan are reviewed.

State acceptance was evaluated formally after the public comment period on the Proposed Plan. The Proposed Plan and this ROD were prepared in partnership with USEPA and NJDEP representatives. The

NJDEP approved both the FS and the Proposed Plan for Area B groundwater. It is anticipated that the NJDEP will concur with the selection of the preferred remedial alternatives for Area B groundwater.

NJDEP acceptance is anticipated for alternative 5B, Expedited In Situ Enhanced Bioremediation. The primary NJDEP comment to the draft final FS was that the treatment duration for the selected remedy was too long. Based upon the NJDEP concern over treatment duration, the Army modified the preferred alternative with an expedited treatment time of seven years.

2.11.3.2 Community Acceptance

This criterion addresses the issues and concerns the public may have regarding each of the alternatives. This criterion is evaluated formally when comments on the Proposed Plan are reviewed.

A final Proposed Plan for Area B groundwater was completed and released to the public in October 2005 at the information repositories listed in Section 2.3. The notice of availability of these documents was published on September 30, 2005 in the New Jersey Star Ledger and the Daily Record. A public comment period was held from October 6, 2005 to November 7, 2005, during which comments from the public were received. In general, the community appears to be in support of the Selected Remedy for Area B groundwater. Responses to written comments received during the public comment period are presented in the Responsiveness Summary (Section 3.0). A public meeting was held on October 6, 2005 to inform the public about the Selected Remedy for Area B groundwater and to seek public comments. A community relations program has been established and is maintained for Picatinny.

Community acceptance was evaluated formally after the public comment period on the Proposed Plan. Community acceptance is addressed in the Responsiveness Summary, Section 3.0, of this ROD.

2.12 PRINCIPAL THREAT WASTE

The NCP establishes an expectation that USEPA will use treatment to address the principal threats posed by a site wherever practicable (NCP §300.430[a])[1][iii][A]). Identifying principal threat wastes combines concepts of both hazard and risk. In general, principal threat wastes are those source materials considered to be highly toxic or highly mobile, and that generally cannot be contained in a reliable manner or would present a significant risk to human health or the environment should exposure occur. Conversely, non-principal wastes are those source materials that generally can be reliably contained and that would present only a low risk in the event of exposure.

No principal threat wastes remain at Area B as there are no remaining primary and secondary sources of VOCs. Groundwater contamination at Area B is the result of historical spills directly onto the ground surface.

2.13 SELECTED REMEDY

The Selected Remedy for Area B groundwater is **Alternative 5B: Expedited In Situ Enhanced Bioremediation**.

2.13.1 Summary of the Rationale for the Selected Remedy

The remedy for Area B groundwater was chosen through application of the CERCLA process. This alternative will aggressively eliminate dissolved chlorinated solvent mass in groundwater in Area B, achieving RAOs in a relatively short time frame; thereby reducing short-term risks and better assuring long term effectiveness and permanence in a cost-effective manner. The selected remedy meets the threshold criteria and provides the best overall balance of tradeoffs in terms of the five balancing criteria:

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, and volume;
- Short-term effectiveness;
- Implementability; and,
- Cost.

2.13.2 Description of the Selected Remedy

2.13.2.1 Alternative 5B: Expedited In Situ Enhanced Bioremediation

This enhanced bioremediation system will consist of introduction of a biostimulant via direct-push injection, constructed wells, or both, to increase the rate at which natural microbial degradation of COCs can proceed to RAOs. Such a system will assure protection of potential sensitive receptors from chemical constituents in groundwater in excess of chemical-specific ARARs within seven years. On an equivalent basis:

- Injection via wells along up to six (6) linear traverses of eleven (11) wells each in the unconfined aquifer, oriented perpendicularly to groundwater flow and spaced hydraulically downgradient based on groundwater velocities; and
- Up to three (3) traverses of eleven (11) wells each in the upper semi-confined aquifer, having the same orientation and aquifer specific spacing, will be installed to deliver HRC or a similar reagent to the groundwater. Barrier lines of wells may be installed incrementally, beginning with the most upgradient traverse relative to the highest dissolved phase concentrations, followed by installation of successive lines hydraulically downgradient as the resolution of COC mass reduction at one line is realized. The Remedial Design will detail the final optimum injection network, arrived at through use of an area specific groundwater flow, and COC fate numerical model.

The major components of this selected remedy include:

- Injection of a biostimulant into the subsurface. The expedited restoration timeframe will be achieved either through direct push biostimulant injection events or multiple injections utilizing installed wells over an expanded treatment area. To achieve the 7-year restoration time, the entire groundwater plume will be actively treated via a total of 500 biostimulant injection points or, alternatively, up to 99 installed injection wells. **Figure 13** illustrates the conceptual design of this remedial action with the direct-push layout.
- Permit equivalents will be required to inject the chosen biostimulant(s) into the subsurface. In addition, permit equivalents will be required for well installation and construction within wetland areas. The enhanced bioremediation system itself will require an engineering design.
- In order to implement the enhanced bioremediation system, design and implementation plans will be required.
- Since contamination would remain on-site while active remediation is taking place, LUCs would be required as part of this alternative. LUCs would prevent human exposure to contaminated groundwater and protect construction associated with the remedial technology. The specific provisions and requirements of the LUC portion of this remedy necessary to ensure land use remains safe and appropriate for the level of protection afforded by the remedial action will be detailed as part of the remedial design after the ROD is signed. The following objectives will be met by implementation of LUCs:
 - Prohibition of groundwater use until such time as contaminant levels do not exceed site cleanup levels;
 - Maintain integrity of injection wells and monitoring wells necessary to implement the remedy.
 - Prohibit excavation without safeguards (e.g., measures to prevent exposure to contaminated groundwater and vapor) in all areas below the water table in the plume footprint.

Within 90 days of ROD signature, the Army will prepare and submit to the USEPA for review and approval a LUC remedial design that shall contain implementation and maintenance actions, including periodic inspections. In addition, the Army shall conduct five-year reviews in accordance with CERCLA 121 and the NCP to ensure that the remedy is and will be protective of human health and the environment. When concentrations of COCs fall below the remedial goals, the groundwater monitoring program will be discontinued upon an agreed-upon exit strategy and documented in the next five-year review.

Summary of the Estimated Remedy Costs

The total project estimated present worth cost, if approved, is \$1,548,200 for Area B groundwater. The costs associated with Alternative 5B are follows:

Estimated Capital Cost: \$1,143,600

Estimated O&M Cost: \$404,600

Present Worth: \$1,548,200

The cost information in this section is based on the best available information regarding the anticipated scope of the remedial alternatives, with flexibility in final biostimulant(s) and delivery method(s). Details on the cost items are presented in the *Final FS for Area B Groundwater* (IT, 2002). Changes in the cost elements are likely to occur as a result of new information and data collected during the work plan phase. Major changes may be documented in the form of a memorandum in the Administrative Record file, an Explanation of Significant Differences, or a ROD amendment. This is an order-of-magnitude engineering cost estimate that is expected to be within +50 to -30 of the actual project cost. The lifetime O&M cost was calculated with a seven percent discount rate.

2.13.3 Expected Outcomes of the Selected Remedy

The preferred alternative will address the chlorinated solvents at the site by accelerating the biological degradation of these chemicals. Such biological degradation converts these chemicals to innocuous end products. It is expected that the full-scale treatment will reduce contaminant concentrations to ARARs, which are protective of the identified at-risk receptors.

2.14 STATUTORY DETERMINATIONS

The selected remedy satisfies the statutory requirements of CERCLA §121 and the NCP, as described below.

2.14.1 Protection of Human Health and the Environment

The preferred alternative for Area B groundwater relies on proven, active treatment processes to aggressively reduce concentrations of hazardous substances in groundwater to levels below ARARs to be protective of at-risk receptors. Aggressive in-situ treatment will best assure protection of human health and the environment.

2.14.2 Compliance with ARARs

The preferred alternative for Area B groundwater is expected to comply with the chemical-specific ARARs for groundwater presented in **Table 9** within seven years.

Because of the interconnectivity of groundwater and surface water in Area B, surface water criteria are expected to be met as well.

The selected alternative includes institutional controls to assure protection of the human receptors. The action- and location-specific ARARs would be met by the preferred alternative with the proper permit equivalents. The selected alternative treats the targeted areas of contamination and involves temporary staging of equipment and personnel within wetland areas. Location-specific ARARs presented in **Table 10** will be satisfied because none of the wetlands or stream encroachment areas will be affected by implementation of the LUCs processes in the groundwater and surface water.

Action-specific ARARs presented in **Table 11** will be met by obtaining appropriate permit equivalents. All personnel will be properly trained to handle hazardous materials in accordance with Occupational Safety and Health Administration Act 29 CFR 1910.

2.14.3 Cost Effectiveness

In the lead agency's judgment, the Selected Remedy is cost effective and represents a reasonable value in the money to be spent. In making this determination, the following definition was used: "A remedy shall be cost-effective if its costs are proportional to its overall effectiveness." (NCP §300.430(f)(1)(ii)(D)). This objective was accomplished by evaluating the "overall effectiveness" of those alternatives that satisfied the threshold criteria (i.e., were both protective of human health and the environment, and were ARAR-compliant). Overall effectiveness was evaluated by assessing the five balancing criteria in combination

(long-term effectiveness and permanence; short term effectiveness; reduction of toxicity and mobility, or volume through treatment; implementability; and cost). Overall effectiveness was then compared to costs to determine cost effectiveness. The relationship of the overall effectiveness of this remedial alternative was determined to be proportional to its costs; hence, this alternative represents a reasonable value for the money to be spent.

The estimated present worth cost of the Selected Remedy for Area B groundwater totals approximately \$1,548,200. Although Alternative 1 (No Action) has no associated costs and under this alternative natural attenuation of contaminants in groundwater may also occur, this alternative affords no mechanisms to reduce the potential human exposures to the contaminants and to estimate and verify the natural attenuation rates. Alternative 2 is the most cost effective of the alternatives. Alternative 5A, In Situ Enhanced Bioremediation, has the lowest capital cost and lowest O&M cost, making it the most cost effective of the active alternatives. Alternatives 3 and 4 have similar capital and O&M costs. Alternative 5B, Expedited In Situ Enhanced Bioremediation, has a significantly lower cost than Alternatives 3 and 4, and a slightly higher cost than Alternative 5A.

The Army believes that the Selected Remedy is cost effective and the additional cost compared to Alternative 1 (No Action) provides a significant increase in protection to human health and the environment. The expedited timeframe of the selected alternative also addresses the USEPA concerns over the proximity of the plume to the southern boundary of Picatinny Arsenal.

2.14.4 Utilization of Permanent Solutions and Alternative Treatment Technologies (or Resource Recovery Technologies) to the Maximum Extent Practicable

The Army has determined that the Selected Remedy for Area B groundwater represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a practicable manner at the site. The Army has determined that the Selected Remedy for Area B groundwater provides the best balance of trade-offs in terms of the five balancing criteria, while also considering:

- The statutory preference for treatment as a principal element;
- Bias against off-site treatment and disposal; and
- Regulatory and community acceptance.

The Selected Remedy for Area B groundwater employs active treatment to reduce contaminant concentrations to levels below ARARs, negating the potential for risk that was identified as part of the baseline risk assessment. The Selected Remedy for Area B groundwater satisfies the criteria for long-term effectiveness by providing a practical, permanent remedy using an in situ biodegradation treatment methodology. The selected remedy achieves short-term effectiveness by plume degradation through active treatment in the shortest amount of time. In addition, further reduction of risks could be accomplished through proper implementation of LUCs. The Selected Remedy for Area B groundwater does not present short-term risks that cannot be effectively controlled through safe work practices. The Selected Remedy is the most easily implemented of the engineered alternatives.

2.14.5 Preference for Treatment as a Principal Element

The Selected Remedy for Area B groundwater uses active treatment to address the Area B contaminant plumes. The Selected Remedy provides an optimal implementation timeframe commensurate with an effective use of funding; therefore, it is much more cost effective than the technologies that utilize passive treatment.

2.14.6 Five-Year Review Requirements

Because this remedy will result in hazardous substances remaining on-site above levels that allow for unlimited use and unrestricted exposure, statutory reviews will be conducted every five years until RAOs have been achieved. Five-year reviews will ensure that the remedy is, or will be, protective of human health and the environment. A five-year review of this remedy is scheduled to occur in 2011.

3.0 PART 3: RESPONSIVENESS SUMMARY

The final component of the ROD is the Responsiveness Summary. The purpose of the Responsiveness Summary is to provide a summary of the stakeholders' comments, concerns, and questions about the Selected Remedy for Area B groundwater and the Army's responses to these concerns.

Some community concern has been expressed because there are still COCs in the soil at Area B. The Army, USEPA, and NJDEP have considered all comments and concerns, summarized below, in selecting the final cleanup methods for Area B groundwater at Picatinny.

3.1 PUBLIC ISSUES AND LEAD AGENCY RESPONSES

As of the date of this ROD, the Army endorses the preferred alternative for Area B groundwater of Expedited Enhanced Bioremediation with HRC for the chlorinated VOC plumes. The USEPA and NJDEP support the Army's plan. Comments received during the public comment period on the Proposed Plan are summarized below.

3.1.1 Summary of Comments Received During the Public Meeting on the Proposed Plan and Agency Responses

The following text summarizes the Agency responses to comments received during the public meeting on October 6, 2005.

Comment 1: The commenter, Michael Glaab, is a resident of Jefferson Township and is on the Picatinny Arsenal Restoration Advisory Board. He is very encouraged by the aggressive clean-up program. He complimented everyone involved in the environmental clean-up program, especially Ted Gabel and everyone else who's working with Ted. Mr. Glaab wanted more details on how the injection by remediation process would clean up the two Arsenal RODs and whether they will meet New Jersey state standards for the contaminants of concern.

Response: One of the goals is to meet New Jersey state criteria and the selected alternative was selected based in part on the fact that the NJDEP criteria will be met in seven years upon implementation of this alternative.

Comment 2: Michael Glaab further noted that there are still contaminants of concern in the ground and that a decision was made to assume that the previous clean-up program was sufficient. In addition, he noted that Green Pond Brook (GPB) was nearby and doesn't want the contaminants to migrate to GPB.

Response: Contamination remaining at the site is adequately addressed through the previously implemented remedial action for all other media as part of the Site 20/24 ROD. Quarterly inspections are conducted to ensure the continued integrity of the implemented remedial action for the remaining soil contamination. GPB does not appear to be impacted by the groundwater contamination in Area B groundwater and the possibility of future impact to the brook from Area B groundwater will be nullified upon implementation of the selected remedy.

3.2 TECHNICAL AND LEGAL ISSUES

No technical or legal issues were raised on the Selected Remedy.

4.0 PART 4: REFERENCES

Accutech Remedial Systems Inc., 2000. Final Treatability Studies of Chlorinated VOC degradation with Iron Powder

Dames and Moore (D&M). 1998. Picatinny Arsenal Phase I Remedial Investigation Report. Prepared for U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland. Final Document.

IT Corporation (IT). 2002. Final Area B Groundwater Feasibility Study. Prepared for the U.S. Army Corps of Engineers, Baltimore District. Contract No. DACA-31-95-D-0083.

Shaw Environmental, Inc. (Shaw), 2001. Site 20/24 Record of Decision. November 2001. Final Document.

Shaw Environmental, Inc. (Shaw), 2003. Work Plan for Area B Site 20/24 Groundwater HRC/ORC Pilot Study, Picatinny, New Jersey. Prepared for U.S. Army Corps of Engineers- Baltimore District. Contract No. DACA-31-D-95-0083. September 2003. Final Document.

Shaw Environmental, Inc. (Shaw). 2005. Proposed Plan for Area B Groundwater Picatinny, New Jersey. Final. Prepared for the U.S. Army Corps of Engineers, Baltimore District. September.

Shaw Environmental, Inc. (Shaw). 2005a. Picatinny Arsenal Task Order 19 Site 20/24 – Site Closure Report. Draft Final. Prepared for the U.S. Army Corps of Engineers, Baltimore District. October 2005.

Shaw Environmental, Inc. (Shaw), 2005b. Area B (Site 20/24) HRC and ORC Groundwater Pilot Study Report, Picatinny, New Jersey. Prepared for U.S. Army Corps of Engineers- Baltimore District. Contract No. DACA-31-D-95-0083. July 2005. Draft Final Document.

United States Environmental Protection Agency (USEPA), 2002. Site 20/24 Record of Decision. June 2002. Signature of Final Document.

Tables

TABLE 1
SUMMARY OF XYLENE CONCENTRATIONS IN MW24-3

Monitoring Well	Total Xylenes (µg/L)						
	Cleanup Level		Analytical Results				
	NJ MCL (2002)	NJ MCL (2005)	1998	1999	3-Oct	4-May	4-Nov
MW24-3	40	1,000	2,011	410	42.7	26	47

Notes:

▪ NJ MCL - New Jersey Maximum Contaminant Level

TABLE 2
SUMMARY OF DETECTIONS IN THE UNCONFINED AQUIFER - 1994, 1997, 1998, & 1999 SAMPLING EVENTS

Chemical	Frequency of Detection				Range of Concentrations				Location of Highest Concentration			
	1994 Data	1997 Data	1998 Data	1999 Data	1994 Data	1997 Data	1998 Data	1999 Data	1994 Data	1997 Data	1998 Data	1999 Data
VOLATILES (µg/L)												
Acetone	2 / 21	0 / 12	0 / 21	0 / 17	24.0 - 72.0	---	---	---	DM20-1 (11/5/93)	---	---	---
Benzene	0 / 21	3 / 12	4 / 21	3 / 19	---	2.00 - 3.15	1.29 - 1.89	1.90 - 16.0	---	20/24HP-1	MW24-3	20/24MW-3
Bromomethane	0 / 21	2 / 12	0 / 21	0 / 19	---	2.22 - 4.16	---	---	---	20/24HP-1	---	---
2-Butanone	0 / 21	0 / 12	3 / 21	0 / 17	---	---	2.19 - 5.45	---	---	---	20/24HP-21	---
Carbon disulfide	0 / 21	0 / 12	0 / 21	1 / 19	---	---	---	0.170	---	---	---	20/24PZ-8
Carbon tetrachloride	1 / 21	0 / 12	0 / 21	0 / 19	10.0	---	---	---	MW24-3 (7/18/94)	---	---	---
Chlorobenzene	2 / 21	1 / 12	3 / 21	1 / 19	13.0 - 20.0	3.20	1.10 - 12.5	12.0	MW24-3 (7/18/94)	20/24HP-3	20/24HP-17A	MW24-3 (12/6/99)
Chloroethane	0 / 21	0 / 12	0 / 21	1 / 19	---	---	---	1.50	---	---	---	MW-18 (6/23/99)
Chloroform	0 / 21	0 / 12	0 / 21	4 / 19	---	---	---	0.110 - 0.140	---	---	---	20/24PZ-1
Chloromethane	0 / 21	6 / 12	0 / 21	0 / 19	---	3.38 - 8.62	---	---	---	20/24HP-1	---	---
1,2-Dichloroethene (total)	0 / 21	4 / 12	0 / 1	NT	---	3.58 - 308	---	NT	---	20/24HP-12	---	NT
1,1-Dichloroethene	0 / 21	1 / 12	2 / 21	1 / 19	---	9.17	1.10 - 1.23	0.425	---	20/24HP-9	20/24HP-25	20/24MW-5
cis-1,2-Dichloroethene	NT	NT	2 / 20	5 / 19	NT	NT	72.4 - 162	0.180 - 250	NT	NT	20/24HP-25	20/24MW-3
trans-1,2-Dichloroethene	NT	NT	2 / 21	2 / 19	NT	NT	0.899 - 10.6	0.150 - 1.35	NT	NT	20/24HP-25	20/24MW-5
Ethane	NT	NT	NT	2 / 6	NT	NT	NT	50.0 - 67.0	NT	NT	NT	20/24MW-3
Ethene	NT	NT	NT	3 / 6	NT	NT	NT	2.85 - 200	NT	NT	NT	20/24MW-3
Ethyl benzene	2 / 21	0 / 12	1 / 21	0 / 19	78.0 - 400	---	134	---	MW24-3 (7/18/94)	---	MW24-3	---
Methane	NT	NT	NT	5 / 6	NT	NT	NT	15.5 - 14,000	NT	NT	NT	MW24-3
4-Methyl-2-pentanone (MIBK)	1 / 21	0 / 12	0 / 21	0 / 19	26.0	---	---	---	MW24-3 (4/12/94)	---	---	---
Methylene chloride	0 / 21	0 / 12	0 / 21	5 / 19	---	---	---	0.150 - 2.90	---	---	---	20/24PZ-5
Toluene	2 / 21	0 / 12	3 / 21	2 / 19	3.00 - 10.0	---	0.620 - 1.43	0.0560 - 0.330	MW24-3 (7/18/94)	---	MW24-3	20/24PZ-5
1,1,1-Trichloroethane	1 / 21	0 / 12	0 / 21	0 / 19	90.0	---	---	---	MW24-3 (7/18/94)	---	---	---
Trichloroethene	0 / 21	2 / 12	2 / 21	1 / 19	---	2.77 - 34.4	0.828 - 22.2	18.5	---	20/24HP-5	20/24HP-25	20/24MW-5
Vinyl chloride	2 / 21	3 / 12	4 / 21	7 / 19	99.0 - 160	66.6 - 1,520	3.04 - 273	1.70 - 1,200	MW-18 (7/13/94)	20/24HP-9	20/24HP-24	20/24MW-3
m-Xylenes	1 / 21	NT	NT	NT	400	NT	NT	NT	MW24-3 (4/12/94)	NT	NT	NT
Total Xylenes	2 / 21	1 / 12	2 / 21	3 / 19	71.0 - 120	2.85	3.52 - 2,010	410 - 700	MW24-3 (4/12/94)	20/24HP-3	MW24-3	MW24-3 (3/25/99)
SEMIVOLATILES (µg/L)												
di-n-Butylphthalate	0 / 21	1 / 12	4 / 21	NT	---	9.10	2.62 - 8.19	NT	---	20/24HP-9	20/24HP-24	NT
Butylbenzyl phthalate	0 / 21	0 / 12	3 / 21	NT	---	---	6.41 - 22.2	NT	---	---	MW24-3	NT
2-Chloronaphthalene	0 / 21	1 / 12	0 / 21	NT	---	3.10	---	NT	---	20/24HP-4	---	NT
Dibenzofuran	0 / 21	0 / 12	1 / 21	NT	---	---	1.71	NT	---	---	MW24-3	NT
1,4-Dichlorobenzene	1 / 21	0 / 12	0 / 21	NT	3.30	---	---	NT	MW24-3 (7/18/94)	---	---	NT
2,4-Dimethylphenol	1 / 21	0 / 12	1 / 21	NT	9.80	---	16.3	NT	MW24-3 (7/18/94)	---	MW24-3	NT
bis(2-Ethylhexyl)phthalate	0 / 21	0 / 12	2 / 21	NT	---	---	11.1 - 75.6	NT	---	---	20/24HP-24	NT
2-Methylnaphthalene	2 / 21	0 / 12	1 / 21	NT	2.40 - 6.60	---	2.75	NT	MW24-3 (7/18/94)	---	MW24-3	NT
4-Methylphenol	1 / 21	0 / 12	0 / 21	NT	3.60	---	---	NT	MW24-3 (7/18/94)	---	---	NT
Naphthalene	2 / 21	2 / 12	2 / 21	NT	8.90 - 23.0	2.00 - 4.10	3.36 - 5.57	NT	MW24-3 (7/18/94)	20/24HP-4	MW24-3	NT
n-Nitrosodiphenylamine	0 / 21	0 / 12	1 / 21	NT	---	---	101	NT	---	---	20/24HP-24	NT
3-Nitrotoluene	1 / 21	NT	NT	NT	21.0	NT	NT	NT	MW24-4A (7/12/94)	NT	NT	NT
Phenanthrene	0 / 21	0 / 12	2 / 21	NT	---	---	2.22 - 2.59	NT	---	---	MW24-3	NT
PESTICIDES (µg/L)												
Aldrin	2 / 21	0 / 12	NT	NT	0.0734 - 0.0794	---	NT	NT	MW-15 (4/13/94)	---	NT	NT
delta-BHC	4 / 21	0 / 12	NT	NT	0.00383 - 7.30	---	NT	NT	MW24-4A (7/12/94)	---	NT	NT
gamma-BHC (Lindane)	2 / 21	0 / 12	NT	NT	0.00426 - 0.00551	---	NT	NT	MW24-4A (7/12/94)	---	NT	NT
Endosulfan sulfate	7 / 21	0 / 12	NT	NT	0.00304 - 0.0456	---	NT	NT	MW-15 (11/4/93)	---	NT	NT
Heptachlor	4 / 21	0 / 12	NT	NT	0.00369 - 0.00583	---	NT	NT	DM24-1 (7/13/94)	---	NT	NT
Heptachlor epoxide	1 / 21	0 / 12	NT	NT	0.0119	---	NT	NT	MW24-2A (4/12/94)	---	NT	NT
Isodrin	4 / 21	NT	NT	NT	0.00339 - 0.0276	NT	NT	NT	MW-15 (4/13/94)	NT	NT	NT
EXPLOSIVES (µg/L)												
Nitrocellulose	13 / 21	NT	NT	NT	422 - 1,130	NT	NT	NT	DM20-2 (7/13/94)	NT	NT	NT
PETN	2 / 21	NT	NT	NT	2.21 - 4.52	NT	NT	NT	DM24-1 (11/5/93)	NT	NT	NT
Tetryl	2 / 13	NT	NT	NT	1.13 - 13.0	NT	NT	NT	MW24-3 (7/18/94)	NT	NT	NT
1,3,5-Trinitrobenzene	3 / 13	NT	NT	NT	0.479 - 1.91	NT	NT	NT	MW24-3 (7/18/94)	NT	NT	NT
2,4,6-Trinitrotoluene	1 / 13	NT	NT	NT	6.01	NT	NT	NT	MW24-3 (7/18/94)	NT	NT	NT
HYDROGEN (nM)												
Hydrogen	NT	NT	NT	4 / 4	NT	NT	NT	1.10 - 1.60	NT	NT	NT	MW24-3

TABLE 2
SUMMARY OF DETECTIONS IN THE UNCONFINED AQUIFER - 1994, 1997, 1998, & 1999 SAMPLING EVENTS

Chemical	Frequency of Detection				Range of Concentrations				Location of Highest Concentration			
	1994 Data	1997 Data	1998 Data	1999 Data	1994 Data	1997 Data	1998 Data	1999 Data	1994 Data	1997 Data	1998 Data	1999 Data
METALS (µg/L)												
Aluminum	19 / 20	NT	NT	NT	152 - 40,800	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Antimony	1 / 20	NT	0 / 8	NT	70.1	NT	---	NT	MW24-2A	NT	---	NT
Arsenic	16 / 20	NT	4 / 8	NT	2.53 - 35.2	NT	2.00 - 33.0	NT	MW-18 (11/6/93)	NT	MW-18	NT
Barium	20 / 20	NT	NT	NT	16.4 - 1,190	NT	NT	NT	MW-18 (7/13/94)	NT	NT	NT
Beryllium	4 / 20	NT	0 / 8	NT	1.14 - 2.92	NT	---	NT	DM20-1 (7/13/94)	NT	---	NT
Calcium	20 / 20	NT	NT	NT	10,600 - 197,000	NT	NT	NT	MW-18 (7/13/94)	NT	NT	NT
Chromium	6 / 20	NT	NT	NT	19.3 - 92.0	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Cobalt	2 / 20	NT	NT	NT	32.9 - 40.8	NT	NT	NT	MW24-2A	NT	NT	NT
Copper	4 / 20	NT	NT	NT	19.9 - 170	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Iron	20 / 20	NT	NT	NT	6,370 - 178,000	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Lead	12 / 20	NT	NT	NT	6.49 - 123	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Magnesium	20 / 20	NT	NT	NT	3,480 - 66,600	NT	NT	NT	MW24-2A	NT	NT	NT
Manganese	20 / 20	NT	8 / 8	NT	288 - 3,840	NT	230 - 1,400	NT	MW24-2A	NT	MW24-3	NT
Mercury	4 / 20	NT	NT	NT	0.100 - 0.315	NT	NT	NT	MW24-3 (4/12/94)	NT	NT	NT
Nickel	2 / 20	NT	NT	NT	40.3 - 79.5	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Potassium	19 / 20	NT	NT	NT	1,400 - 9,350	NT	NT	NT	DM24-1 (4/13/94)	NT	NT	NT
Silver	3 / 20	NT	NT	NT	0.475 - 3.14	NT	NT	NT	MW24-3 (7/18/94)	NT	NT	NT
Sodium	20 / 20	NT	NT	NT	1,390 - 830,000	NT	NT	NT	MW-18 (7/13/94)	NT	NT	NT
Vanadium	3 / 20	NT	NT	NT	29.9 - 146	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
Zinc	15 / 20	NT	NT	NT	24.1 - 440	NT	NT	NT	DM20-1 (7/13/94)	NT	NT	NT
ANIONS (µg/L)												
Chloride	NT	NT	NT	5 / 6	NT	NT	NT	24,900 - 1,240,000	NT	NT	NT	MW-18
Nitrate	NT	NT	NT	2 / 6	NT	NT	NT	10.0	NT	NT	NT	20/24MW-3
Sulfate	NT	NT	NT	5 / 6	NT	NT	NT	270 - 86,900	NT	NT	NT	20/24MW-5
Sulfide	NT	NT	NT	1 / 6	NT	NT	NT	430	NT	NT	NT	DM24-1
DOC (µg/L)												
Dissolved Organic Carbon	NT	NT	NT	5 / 5	NT	NT	NT	7,750 - 30,500	NT	NT	NT	MW24-3
TOC (µg/L)												
Total Organic Carbon	6 / 6	NT	NT	NT	4,940 - 24,200	NT	NT	NT	MW24-3 (7/18/94)	NT	NT	NT
RADIOLOGICALS (pCi/L)												
Gross alpha	3 / 3	NT	NT	NT	1.00 - 1.90	NT	NT	NT	DM20-2 (4/13/94)	NT	NT	NT
Gross beta	3 / 3	NT	NT	NT	6.80 - 21.0	NT	NT	NT	DM20-2 (7/13/94)	NT	NT	NT

TABLE 3
SUMMARY OF DETECTIONS IN THE UPPER SEMICONFINED AQUIFER - 1994, 1998, & 1999 SAMPLING EVENTS

Chemical	Frequency of Detection			Range of Concentrations			Location of Highest Concentration		
	1994 Data	1998 Data	1999 Data	1994 Data	1998 Data	1999 Data	1994 Data	1998 Data	1999 Data
VOLATILES (µg/L)									
Acetone	0 / 2	0 / 4	3 / 31	---	---	5.00 - 9.80	---	---	20/24HP-31C
Benzene	0 / 2	0 / 4	8 / 31	---	---	0.0890 - 0.460	---	---	20/24HP-27A
2-Butanone	0 / 2	0 / 4	4 / 31	---	---	1.40 - 5.40	---	---	20/24HP-33
Carbon disulfide	0 / 2	0 / 4	12 / 31	---	---	0.120 - 0.530	---	---	20/24HP-26A
Dichlorodifluoromethane	NT	0 / 4	1 / 31	NT	---	0.300	NT	---	20/24HP-30A
1,2-Dichloroethane	0 / 2	0 / 4	1 / 31	---	---	0.0980	---	---	20/24HP-29B
1,1-Dichloroethene	0 / 2	2 / 4	7 / 31	---	11.8 - 21.0	0.160 - 12.0	---	20/24MW-2 (12/10/98)	20/24MW-2 (6/23/99)
cis-1,2-Dichloroethene	NT	2 / 4	22 / 31	NT	372 - 640	0.100 - 600	NT	20/24MW-2 (12/10/98)	20/24MW-2 (6/23/99)
trans-1,2-Dichloroethene	NT	2 / 4	3 / 31	NT	2.81 - 4.10	3.20 - 12.0	NT	20/24MW-2 (12/10/98)	20/24MW-2 (03/25/99 & 6/23/99)
Ethane	NT	NT	2 / 2	NT	NT	1.20 - 20.0	NT	NT	20/24MW-2 (12/8/99)
Ethene	NT	NT	1 / 2	NT	NT	170	NT	NT	20/24MW-2 (12/8/99)
Methane	NT	NT	2 / 2	NT	NT	170 - 360	NT	NT	20/24MW-2 (12/8/99)
Methylene chloride	0 / 2	0 / 4	2 / 31	---	---	2.60 - 2.70	---	---	20/24HP-27A
Tetrachloroethene	0 / 2	0 / 4	17 / 31	---	---	0.280 - 73.0	---	---	20/24HP-28C
Toluene	0 / 2	0 / 4	3 / 31	---	---	0.100 - 0.200	---	---	20/24HP-27A
Trichloroethene	0 / 2	2 / 4	9 / 31	---	18.0 - 26.2	0.140 - 24.0	---	20/24MW-2 (8/5/98)	20/24MW-2 (3/25/99)
Vinyl chloride	0 / 2	2 / 4	18 / 31	---	561 - 760	0.150 - 700	---	20/24MW-2 (12/10/98)	20/24MW-2 (6/23/99)
Total Xylenes	0 / 2	0 / 4	2 / 31	---	---	1.60 - 2.00	---	---	20/24HP-27A
EXPLOSIVES (µg/L)									
Nitrocellulose	2 / 2	NT	NT	722 - 989	NT	NT	MW24-2B (7/12/94)	NT	NT
HYDROGEN (nM)									
Hydrogen	NT	NT	2 / 2	NT	NT	0.810 - 1.00	NT	NT	20/24MW-2 (12/8/99)
METALS (µg/L)									
Aluminum	2 / 2	NT	NT	3,400 - 6,080	NT	NT	MW24-2B (4/12/94)	NT	NT
Arsenic	1 / 2	1 / 1	NT	4.10	2.80	NT	MW24-2B (4/12/94)	MW24-2B	NT
Barium	2 / 2	NT	NT	23.0 - 42.0	NT	NT	MW24-2B (4/12/94)	NT	NT
Calcium	2 / 2	NT	NT	32,400 - 35,300	NT	NT	MW24-2B (4/12/94)	NT	NT
Iron	2 / 2	NT	1 / 1	7,320 - 13,700	NT	19,600	MW24-2B (4/12/94)	NT	20/24HP-30D
Lead	2 / 2	NT	NT	7.10 - 7.42	NT	NT	MW24-2B (4/12/94)	NT	NT
Magnesium	2 / 2	NT	NT	12,100 - 14,800	NT	NT	MW24-2B (4/12/94)	NT	NT
Manganese	2 / 2	1 / 1	12 / 12	289 - 465	120	3,080 - 68,100	MW24-2B (4/12/94)	MW24-2B	20/24HP-29D
Potassium	2 / 2	NT	NT	1,520 - 2,920	NT	NT	MW24-2B (4/12/94)	NT	NT
Sodium	2 / 2	NT	NT	9,600 - 9,760	NT	NT	MW24-2B (4/12/94)	NT	NT
Zinc	2 / 2	NT	NT	42.3 - 44.6	NT	NT	MW24-2B (4/12/94)	NT	NT
ANIONS (µg/L)									
Chloride	NT	NT	15 / 15	NT	NT	6,600 - 1,510,000	NT	NT	20/24MW-2 (12/8/99)
Nitrate	NT	NT	6 / 15	NT	NT	100 - 250	NT	NT	20/24HP-26C
Sulfate	NT	NT	15 / 15	NT	NT	14,200 - 77,400	NT	NT	20/24HP-27A
Sulfide	NT	NT	6 / 15	NT	NT	1,100 - 24,000	NT	NT	20/24HP-29A, 20/24HP-29D
DOC (µg/L)									
Dissolved Organic Carbon	0 / 2	NT	1 / 2	---	NT	7.550	---	NT	20/24MW-2 (12/8/99)

Notes:
NT = Not tested.

TABLE 4
SUMMARY OF DETECTIONS IN THE LOWER SEMICONFINED AQUIFER - 1994 & 1998

Chemical	Frequency of Detection		Range of Concentrations		Location of Highest Concentration	
	1994 Data	1998 Data	1994 Data	1998 Data	1994 Data	1998 Data
VOLATILES (µg/L)						
1,1,1-Trichloroethane	1 / 2	0 / 2	2.30	---	MW24-4B (7/12/94)	---
SEMIVOLATILES (µg/L)						
di-n-Butylphthalate	0 / 2	1 / 2	---	3.82	---	MW24-4B
Butylbenzyl phthalate	0 / 2	1 / 2	---	6.67	---	MW24-4B
Phenol	1 / 2	0 / 2	6.00	---	MW24-4B (7/12/94)	---
PESTICIDES (µg/L)						
gamma-BHC (Lindane)	1 / 2	NT	0.00362	NT	MW24-4B (7/12/94)	NT
Endosulfan sulfate	1 / 2	NT	0.0306	NT	MW24-4B (7/12/94)	NT
Isodrin	1 / 2	NT	0.00330	NT	MW24-4B (7/12/94)	NT
EXPLOSIVES (µg/L)						
Nitrocellulose	1 / 2	NT	403	NT	MW24-4B (4/12/94)	NT
PETN	1 / 2	NT	2.46	NT	MW24-4B (4/12/94)	NT
DIOXIN/FURANS (µg/L)						
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1 / 2	0 / 1	0.000165	---	MW24-4B (7/12/94)	---
METALS (µg/L)						
Aluminum	2 / 2	NT	962 - 986	NT	MW24-4B (7/12/94)	NT
Arsenic	2 / 2	1 / 1	3.58 - 5.87	2.40	MW24-4B (4/12/94)	MW24-4B
Barium	2 / 2	NT	14.8 - 28.3	NT	MW24-4B (7/12/94)	NT
Calcium	2 / 2	NT	19,000 - 27,000	NT	MW24-4B (7/12/94)	NT
Iron	2 / 2	NT	1,230 - 1,570	NT	MW24-4B (4/12/94)	NT
Lead	1 / 2	NT	5.16	NT	MW24-4B (7/12/94)	NT
Magnesium	2 / 2	NT	2,070 - 2,780	NT	MW24-4B (4/12/94)	NT
Manganese	2 / 2	1 / 1	56.6 - 76.0	29.5	MW24-4B (4/12/94)	MW24-4B
Potassium	2 / 2	NT	39,800 - 74,100	NT	MW24-4B (7/12/94)	NT
Sodium	2 / 2	NT	30,600 - 33,400	NT	MW24-4B (7/12/94)	NT
Zinc	2 / 2	NT	20.3 - 42.3	NT	MW24-4B (7/12/94)	NT
RADIOLOGICALS (pCi/L)						
Gross alpha	2 / 2	NT	1.70 - 1.90	NT	MW24-4B (7/12/94)	NT
Gross beta	2 / 2	NT	34.0 - 79.0	NT	MW24-4B (7/12/94)	NT

Notes:

NT = Not tested.

TABLE 5
SUMMARY OF DETECTIONS IN SURFACE WATER - 1988, 1993, 1997, & 2003 SAMPLING EVENTS

Compound	Frequency of Detection	Range of Detected Concentrations	Range of Detection Limits	Location(s) of Maximum Detected Concentration	LOC	LOC Source	Exceed LOC?	Number of Hits Exceeding LOC
VOLATILES (ug/L)								
1,2-Dichloroethene (total)	2 - 21	6.5 - 20	0.5 - 5	B-SW24-4	---	---	No	0
Acetone	4 - 26	3.47 - 54	8 - 13	B-SW24-11	---	---	No	0
Methylene chloride	18 - 33	3.1 - 30	1 - 5	B-24-SW-002	2.5	NJSWQS	Yes	18
Trichloroethene	1 - 33	4.31 - 4.31	0.5 - 1.5	B-20-SW-002	1	NJSWQS	Yes	1
Vinyl chloride	3 - 33	10 - 67	1 - 12	B-SW24-4	0.082	NJSWQS	Yes	3
SEMIVOLATILES (ug/L)								
di-n-Octylphthalate	1 - 15	60 - 60	1.5 - 15	B-24-SW-002	---	---	No	0
2,4-Dimethylphenol	1 - 10	27 - 27	4.4 - 5.8	B-SW24-11	380	NJSWQS	No	0
2-Methylphenol	1 - 10	36 - 36	3.6 - 3.9	B-SW24-12	---	---	No	0
4-Methylphenol	1 - 10	39 - 39	0.52 - 2.8	B-SW24-12	---	---	No	0
Benzyl alcohol	2 - 10	20 - 24	0.72 - 4	B-SW24-11	---	---	No	0
bis(2-Ethylhexyl)phthalate	4 - 15	10 - 100	4.8 - 10	B-SW24-4, B-24-SW-004	1.2	NJSWQS	Yes	4
Phenol	1 - 15	21 - 21	2.2 - 10	B-SW24-12	10000	NJSWQS	No	0
Phenolics	4 - 5	4.58 - 6.19	2.5 - 2.5	B-24-SW-003	---	---	No	0
PESTICIDES (ug/L)								
Endosulfan I	3 - 19	0.41 - 0.72	0.023 - 23	B-SW24-12	---	---	No	0
4,4'-DDE	4 - 19	0.02 - 0.55	0.027 - 14	B-SW24-11	0.00022	NJSWQS	Yes	4
4,4'-DDT	2 - 19	0.29 - 0.29	0.034 - 18	B-SW24-10, B-SW24-12	0.00022	NJSWQS	Yes	2
alpha-BHC	5 - 19	0.01 - 0.93	0.0385 - 5.3	B-SW24-7	0.0026	NJSWQS	Yes	5
beta-BHC	1 - 19	0.01 - 0.01	0.024 - 17	B-SW24-9	0.0091	NJSWQS	Yes	1
delta-BHC	4 - 10	0.01 - 0.92	0.0293 - 0.34	B-SW24-10	---	---	No	0
Endosulfan sulfate	4 - 19	0.03 - 0.7	0.0786 - 50	B-SW24-12	62	NJSWQS	No	0
Endrin ketone	1 - 10	0.78 - 0.78	0.0285 - 0.25	B-SW24-8	---	---	No	0
gamma-BHC (Lindane)	2 - 19	0.49 - 0.53	0.0507 - 7.2	B-SW24-8	0.98	NJSWQS	No	0
Heptachlor	3 - 19	0.44 - 0.59	0.0423 - 38	B-SW24-12	0.000079	NJSWQS	Yes	3
Heptachlor epoxide	3 - 19	0.01 - 0.83	0.0245 - 28	B-SW24-8	0.000039	NJSWQS	Yes	3
Isodrin	3 - 19	0.39 - 0.64	0.0562 - 7.8	B-SW24-5	---	---	No	0
EXPLOSIVES (ug/L)								
1,3,5-Trinitrobenzene	2 - 17	0.79 - 1.78	0.21 - 2.1	B-SW24-11	---	---	No	0
2,4,6-Trinitrotoluene	1 - 17	1.12 - 1.12	0.426 - 0.758	B-SW24-12	---	---	No	0
Nitrocellulose	4 - 15	538 - 1150	222 - 949	B-SW24-11	---	---	No	0
Tetryl	1 - 17	1.29 - 1.29	0.631 - 2.04	B-SW24-12	---	---	No	0
DIOXINS/FURANS (ug/L)								
Total heptachlorodibenzofurans	1 - 2	0.3 - 0.3	0.037 - 0.037	C-23-SW-001	---	---	No	0
Total hexachlorodibenzo-p-dioxins	1 - 2	0.45 - 0.45	0.1 - 0.1	C-23-SW-001	---	---	No	0
METALS (ug/L)								
Aluminum	16 - 23	26.5 - 5900	23.5 - 200	B-20/24-SW-023	---	---	No	0
Arsenic	8 - 30	1.04 - 6.62	1 - 10	B-20/24-SW-023	0.017	NJSWQS	Yes	8
Barium	29 - 30	3.1 - 228	2.5 - 200	B-20/24-SW-020	2000	NJSWQS	No	0
Beryllium	1 - 30	0.619 - 0.619	0.5 - 5	B-24-SW-002	6	NJSWQS	No	0

TABLE 5
SUMMARY OF DETECTIONS IN SURFACE WATER - 1988, 1993, 1997, & 2003 SAMPLING EVENTS

Compound	Frequency of Detection	Range of Detected Concentrations	Range of Detection Limits	Location(s) of Maximum Detected Concentration	LOC	LOC Source	Exceed LOC?	Number of Hits Exceeding LOC
Boron	6 - 12	52 - 95.3	50 - 50	B-20/24-SW-013	---	---	No	0
Cadmium	2 - 29	2 - 7.29	0.35 - 6.78	B-20/24-SW-023	3.4	NJSWQS	Yes	1
Calcium	23 - 23	6000 - 75300	1000 - 5000	B-SW24-9	---	---	No	0
Chromium	3 - 30	10.9 - 28.1	3.3 - 16.8	B-20/24-SW-023	92	NJSWQS	No	0
Copper	10 - 30	2.67 - 62.9	2.5 - 25	B-20/24-SW-023	1300	NJSWQS	No	0
Iron	28 - 30	190 - 27800	36.8 - 100	B-20/24-SW-020	---	---	No	0
Lead	14 - 30	1.23 - 69.7	1 - 15	B-20/24-SW-023	5	NJSWQS	Yes	8
Magnesium	23 - 23	2460 - 24800	1000 - 5000	B-SW24-9	---	---	No	0
Manganese	28 - 30	4.3 - 1620	2.5 - 15	B-20/24-SW-020	---	---	No	0
Mercury	2 - 27	0.19 - 0.49	0.092 - 0.72	B-20/24-SW-023	0.05	NJSWQS	Yes	2
Nickel	5 - 30	7.1 - 19.5	4 - 40	B-20/24-SW-023	500	NJSWQS	No	0
Potassium	18 - 23	531 - 6480	1000 - 5000	B-SW24-11	---	---	No	0
Silver	2 - 30	0.36 - 0.92	0.333 - 10	B-SW24-5	170	NJSWQS	No	0
Sodium	23 - 23	2660 - 120000	2290 - 5000	B-SW24-9	---	---	No	0
Strontium	12 - 12	15.3 - 191	1 - 1	B-20/24-SW-020	---	---	No	0
Titanium	5 - 12	2.32 - 36.1	2 - 2	B-20/24-SW-023	---	---	No	0
Vanadium	3 - 23	4.7 - 21.3	4.69 - 50	B-20/24-SW-023	---	---	No	0
Zinc	15 - 29	20.8 - 345	18 - 35.8	B-20/24-SW-023	7400	NJSWQS	No	0
Zirconium	1 - 12	1.71 - 1.71	1 - 1	B-20/24-SW-017	---	---	No	0
ANIONS (ug/L)								
Nitrate	7 - 7	216 - 335	-	B-24-SW-002	10000	NJSWQS	No	0
Nitrite	1 - 7	49 - 49	50 - 50	B-24-SW-002	---	---	No	0
Sulfate	4 - 4	5960 - 14900	-	B-SW24-4	---	---	No	0
RADIOLOGICALS (pCi/L)								
Gross Alpha	1 - 4	0.09 - 0.55	0.39 - 1.2	B-SW24-7	---	---	No	0
Gross Beta	1 - 4	1 - 3	1.27 - 2	B-SW24-7	---	---	No	0

Notes:
 LOC: Level of Concern
 NJSWQS: New Jersey Surface Water Quality Standards
 pCi/L - picoCuries per liter
 ug/L: micrograms per liter

TABLE 6
COC DETERMINATION IN AREA B GROUNDWATER

Contaminant	ARAR (µg/L)	ARAR Source	Maximum Concentration Observed (µg/L)				COC Screening		COC
			1994 Phase 1 RI	1997 ARI	1998 ARI	1999 DGI	Confirmed above ARAR	Plume Distribution	
VOCs									
Benzene	1	NJ GWQS	ND	3.15	1.89	16 ^j	yes	no	no
Carbon Tetrachloride	1	NJ GWQS	10	ND	ND	ND	no	no	no
Chlorobenzene	50	NJ GWQS	20	3.2	12.53	12	no	no	no
1,1-Dichloroethene	1	NJ GWQS	ND	9.17	1.34	0.49	yes	no	no
cis-1,2-Dichloroethene	70	NJ GWQS and Federal MCL, MCLG	ND	NT	165	250	yes	yes	yes
Tetrachloroethene	1	NJ GWQS	ND	ND	ND	42	no	yes	yes
1,1,1-Trichloroethane	30	NJ GWQS	90	ND	ND	ND	no	no	no
Trichloroethene	1	NJ GWQS	ND	34.2	26.2	24	yes	yes	yes
Vinyl Chloride	1	NJ GWQS	160	1520	273	1200	yes	yes	yes
Xylenes (total)	1000	NJ GWQS and Federal MCL, MCLG	120	2.85	2011	700	no	yes	no ⁱ
SEMIVOLATILES									
bis(2-Ethylhexyl)phthalate	3	NJ GWQS	ND	ND	75.6	NT	yes	no	no
n-Nitrosodiphenylamine	10	NJ GWQS	ND	ND	101	NT	yes	no	no
METALS *									
Aluminum	200	NJ GWQS	40800	NT	NT	NT	no	no	no ^a
Antimony	6	NJ GWQS and Federal MCL, MCLG	70.1	NT	ND	NT	no	no	no ^b
Arsenic	3	NJ GWQS	35.2	NT	33	NT	yes	no	no ^c
Iron	300	NJ GWQS	178,000	NT	NT	NT	no	no	no ^d
Lead	5	NJ GWQS	123	NT	NT	NT	no	no	no ^e
Manganese	50	NJ GWQS	3840	NT	1400	NT	yes	no	no ^f
Silver	40	NJ GWQS	3.14	NT	NT	NT	no	no	no ^g
Sodium	50000	NJ GWQS	830000	NT	NT	NT	yes	no	no ^h
RADIOLOGICAL PARAMETERS									
Gross Beta	50	California GWQS	21	NT	NT	NT	no	no	no

Notes:

* Samples analyzed for metals during the Phase I RI were unfiltered and were collected using the bailer-method (not low-flow).

^a Contaminant distribution not indicative of a plume; one detection above ARAR in the upgradient well.

^b Contaminant distribution not indicative of a plume; two detections above ARAR are upgradient and cross-gradient from the site; unlikely due to site activities.

^c Contaminant distribution not indicative of a plume; six detections above ARAR are sporadic and include the upgradient well.

^d Contaminant distribution not indicative of a plume; concentrations in all samples detected above the ARAR, including the upgradient well, unlikely due to site activities.

^e Contaminant distribution not indicative of a plume; one detection above ARARs (DM20-1).

^f Contaminant distribution not indicative of a plume; detected in all samples, above ARARs, highest concentration detected in upgradient well.

^g Contaminant distribution not indicative of a plume; three detections are above TBC guidance.

^h Contaminant distribution not indicative of a plume; one sample detected at concentration above ARAR.

ⁱ ARARs presented in this table based upon NJ MCL at time of the drafting of the Area B FS.

Recent increase in NJ MCL for xylene (1,000 µg/L) and lowered concentrations of xylenes at the site have resulted in no ARAR exceedences for xylenes, thus no longer a COC.

ND - Not Detected

NT - Not Tested

Table 7
Summary of Risks Associated with Hypothetical Future Exposures to Groundwater
Future Land-Use Conditions

Location/Pathway	Cancer Risk	Predominant Chemicals (a)	Non-cancer Hazard Index	Predominant Chemicals (a)
WORKER				
Surficial Unconfined Aquifer				
Ingestion	2×10^{-4}	vinyl chloride, arsenic, beryllium,	9	Iron
Total:	2×10^{-4}		9	
Semiconfined Aquifer				
Ingestion	1×10^{-4}	arsenic, beryllium, 2378-TCDD	9×10^{-1}	—
Total:	1×10^{-4}		9×10^{-1}	
ADULT/CHILD RESIDENT				
Surficial Unconfined Aquifer				
Ingestion	1×10^{-3}	Carbon tetrachloride, vinyl chloride, arsenic, beryllium,	3	Antimony, arsenic, iron, manganese, 1,3,5-Trinitrobenzene
Dermal Contact	5×10^{-9}	—	1×10^{-4}	—
Inhalation	1×10^{-4}	Vinyl chloride	2×10^{-3}	—
Total:	1×10^{-3}		3	
Semiconfined Aquifer				
Ingestion	6×10^{-4}	Arsenic, beryllium, 2378 TCDD	4	Iron
Dermal Contact	5×10^{-6}	2378 TCDD	1×10^{-5}	—
Inhalation	N/A	—	N/A	—
Total:	6×10^{-4}		4	
CHILD RESIDENT				
Surficial Unconfined Aquifer				
Ingestion	3×10^{-4}	Vinyl chloride, arsenic, beryllium	50	Aluminum, antimony, arsenic, iron, manganese, 1,3,5-trinitrobenzene
Dermal Contact	1×10^{-9}	—	2×10^{-4}	—
Inhalation	5×10^{-5}	Vinyl chloride	5×10^{-2}	—
Total:	4×10^{-4}		50	
Semiconfined Aquifer				
Ingestion	2×10^{-3}	Arsenic, beryllium	5	Arsenic, iron
Dermal Contact	8×10^{-7}	—	2×10^{-5}	—
Inhalation	N/A	—	N/A	—
Total:	2×10^{-4}		5	

(a) For carcinogenic compounds, the predominant chemicals had a chemical-specific cancer risk greater than 1×10^{-6} , for noncarcinogenic compounds, the predominant chemicals had a hazard index greater than 1.

(b) The cancer risk for each COPC was less than or equal to 1×10^{-6} or the hazard index for each COPC was less than or equal to 1.

TABLE 8
SUMMARY OF COSTS OF GROUNDWATER REMEDIAL ALTERNATIVES

Alternative	Summary of Cost
Alternative 1	No Costs
Alternative 2	Present Worth \$621,300 O&M \$562,800 Capital Cost \$58,500
Alternative 3	Present Worth \$2,565,000 O&M \$518,200 Capital Cost \$2,046,800
Alternative 4	Present Worth \$2,859,300 O&M \$504,400 Capital Cost \$2,354,900
Alternative 5A	Present Worth \$1,298,900 O&M \$596,400 Capital Cost \$702,500
Alternative 5B	Present Worth \$1,548,200 O&M \$404,600 Capital Cost \$1,143,600
Alternative 9	Present Worth \$3,629,700 O&M \$2,730,500 Capital Cost \$899,200

TABLE 9
CHEMICAL SPECIFIC ARARS FOR AREA B GROUNDWATER

Authority	Law/Regulation	Status	Synopsis of Requirement (s)	Action to be Taken
State	SDWA State MCLs, NJAC 7:10-1 et. Seq.	Relevant and Appropriate	MCLs have been promulgated by the State and regulate contaminants in public drinking water.	The selected remedy will comply with these regulations through expedited in- situ enhanced bioremediation.
	GWQS, NJAC 7:9-6.1 et. Seq.	Applicable	Contaminated groundwater may have to be remediated.	

Notes:

MCL- Maximum Contaminant Level

NJAC- New Jersey Administrative Code

TABLE 10
LOCATION SPECIFIC ARARS FOR AREA B GROUNDWATER

Characteristic	Status	Synopsis of Requirement(s)	Action To Be Taken to Attain Requirement
Wetlands Presence of wetlands as defined in Executive Order 11990 section 7(c) and 40 CFR 6, Appendix A section 4 (j)	TBC	Whenever possible, Federal agency actions must avoid or minimize adverse impacts on wetlands and act to preserve and enhance their natural and beneficial values. Agencies should particularly avoid new construction in wetland areas unless there are no practicable alternatives. Federal agencies shall incorporate wetlands protection consideration into planning, regulating, and decision-making processes.	Substantive permit requirements for stream, wetlands, and/or transition area encroachments during implementation of the specific remedial alternatives.
Flood Plains Within 100-year flood plain as defined in 40 CFR 264.18(b) and NJAC 7:13 (New Jersey Flood Hazard Area Control Regulations).	Applicable	Facility must be designed, constructed, operated, and maintained to prevent washout of any hazardous waste by flooding.	A portion of Area B, along GPB, is within the 100-year flood plain. Flood plain restrictions are specified in the cited law.
Within "lowland and relatively flat area adjoining inland and coastal waters and other flood-prone areas such as offshore islands, including at a minimum that area subject to a 1 percent or greater chance of flooding in any given year." [Executive Order 11988 section 6 (c) and 40 CFR 6, Appendix A and section 4(d)].	Applicable	Federal agencies shall take action to reduce the risk of flood loss; minimize the impact of floods on human safety, health, and welfare; and restore and preserve the natural and beneficial values of flood plains. Federal agencies shall evaluate the potential effects of actions in flood plains and ensure consideration of flood hazards and flood plain management. If action is taken in flood plains, Federal agencies shall consider alternatives to avoid adverse impacts and potential harm.	
Aquifer Recharge Protection Federal Water Pollution Control Act, Section 309 (c) [Fed. Reg. 2946-2948, Jan. 24, 1984].	Relevant and Appropriate	Restricted activities, such as landfill, surface impoundment, waste pile, injection well, or land treatment, over the Unconsolidated Quaternary Aquifer or recharge zone or streamflow source zone of such aquifer in the Rockaway River Basin, NJ.	Remedial activities are limited to prevent any impact to the Rockaway River Basin.
Classification Exemption Area (CEA) Presence of an area that is out of compliance with NJ groundwater chemical-specific ARARs (NJAC 7:9-6.6).	Relevant and Appropriate	Establishes an administrative control on an area that does not comply with GWQS. The CEA administratively prohibits construction of drinking water production wells by circumventing the issuing of a well construction permit in areas where a CEA has been placed.	A CEA has been established for Picatinny

Notes:

TBC- To be considered

TABLE 11
ACTION SPECIFIC ARARS FOR AREA B GROUNDWATER

Action	Law/Regulation	Status	Requirement (s)
Sampling and Analysis	Remediation Technical Requirements, NJAC 7:26E-3	TBC	Requirements of quality assurance for sampling and analysis at remediation sites.
LUC implementation	Institutional Controls – 40 CFR 300.430(a)(iii)(D)	Applicable	USEPA expects to use institutional controls such as water use and deed restrictions to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. Institutional controls may be used during implementation of the remedial action and, where necessary, as a component of the completed remedy. "[t]he use of institutional controls shall not substitute for active response measures as the sole remedy unless such active measures are determined not to be practicable, based on the balancing trade-offs among alternatives that is conducted during the selection of the remedy."
General Remediation	Technical Requirements for Site Remediation, NJAC 7:26E 1, 4-7	TBC	Specifies the minimum technical requirements to investigate and remediate contamination on any site.
	USEPA Office of Solid Waste and Emergency Response (OSWER) Publication 9345.3-03FS, January 1992	TBC	Investigation-derived wastes generated from remedial activities (e.g., drilling mud, purged water, etc.) are required to be properly stored, managed and disposed. Guidance given in the publication includes waste material containment, collection, labeling, etc.
Installation of Wells	Field Sampling Procedures Manual, August 2005	TBC	State guidance and general industry procedures for installation of extraction wells/monitoring wells.

Notes:

TBC- To be considered


Figures

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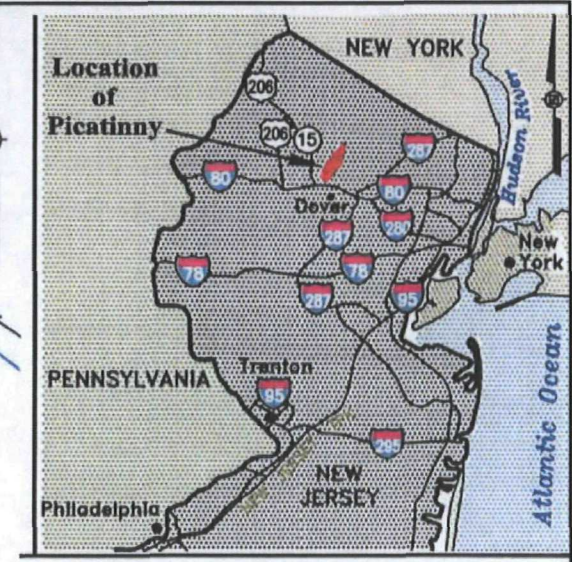
LEGEND

- TREE LINE
- FENCE LINE
- STORM SEWER
- BUILDING
- WATER
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- PAVED ROADWAY
- UNPAVED ROADWAY
- LIMITS OF SOIL CAP
- SITE BOUNDARY

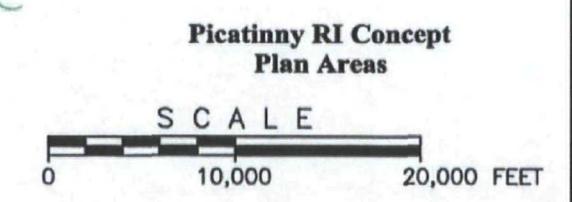
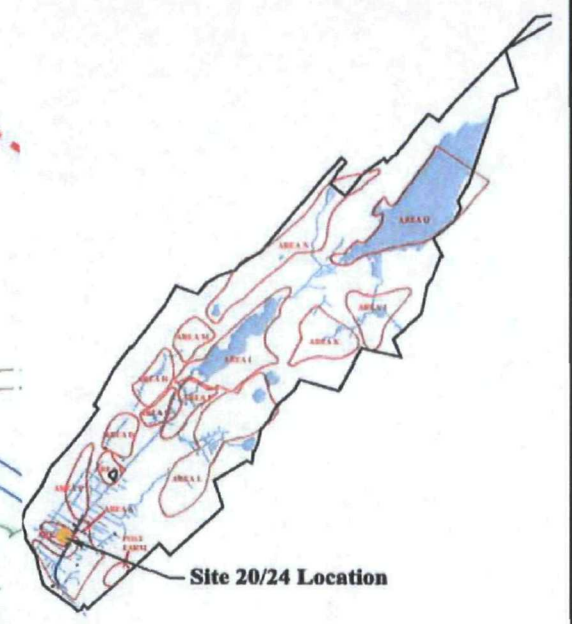


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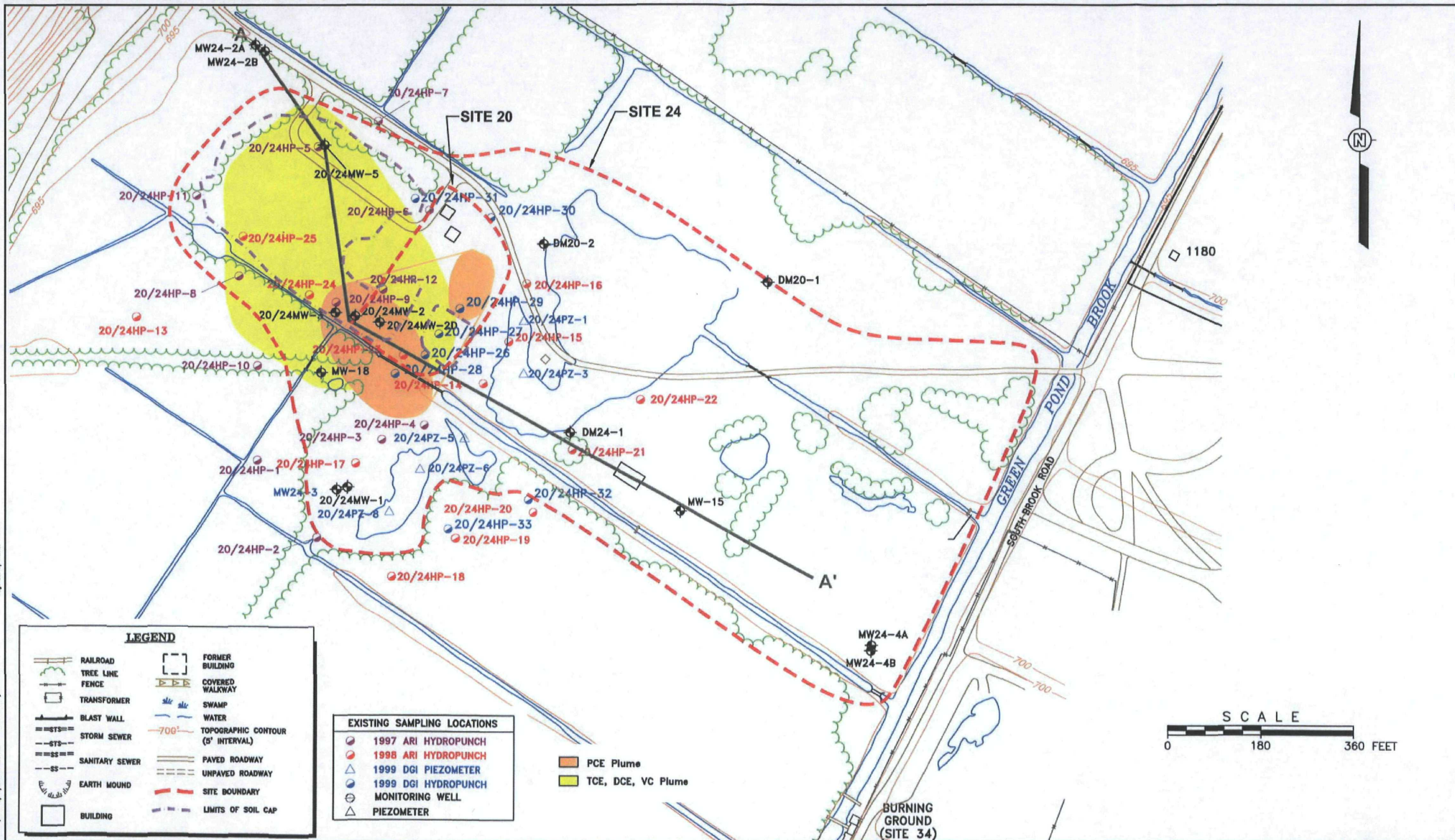
PICATINNY ARESENAL
AREA B RECORD OF DECISION
BOUNDARIES AND VICINITY OF
AREA B (SITE 20/24)
DOVER, NEW JERSEY



LOCATION OF PICATINNY
0 50
MILES



Project Number	GP06PICA.P205.NP001
Drawing Date	12/15/06
Figure	1



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Technical Review K. EYRE	

PICATINNY ARESENAL
 AREA B RECORD OF DECISION
 AREA B GROUNDWATER SAMPLE LOCATIONS
 AND MAIN AREAS/PLUMES OF VOCs
 DOVER, NEW JERSEY

Project Number GP06PICA.P205.NP001
Drawing Date 12/15/06
Figure 2

**PRIMARY
SOURCES
LEAKS FROM:**

**PRIMARY
RELEASE
MECHANISM**

**SECONDARY
SOURCE**

**SECONDARY
RELEASE
MECHANISM**

PATHWAY

RECEPTORS

Former Drum
Storage

Former Small
Container
Storage

Infiltration/
Percolation

Soil

Infiltration/
Percolation

Desorption

Groundwater

Drainage
Ditches and
Landfill Pond

Exposure
Route

Human

Exposure Route	Residents		
	Workers	Adults	Children

Area B Groundwater

Ingestion	●	●	●
Inhalation(Showering)	●	●	●
Dermal (Bathing)	●	●	●



Notes:
Indicates items addressed under
separate CERCLA action.

Soil, surface water and sediment were
addressed under the Site 20/24 ROD.

PICATINNY ARSENAL
AREA B RECORD OF DECISION

CONCEPTUAL SITE MODEL

DOVER, NEW JERSEY

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R. GAN

Project Director
T. LLEWELLYN

Task Manager
K. EYRE

Technical Review
K. EYRE



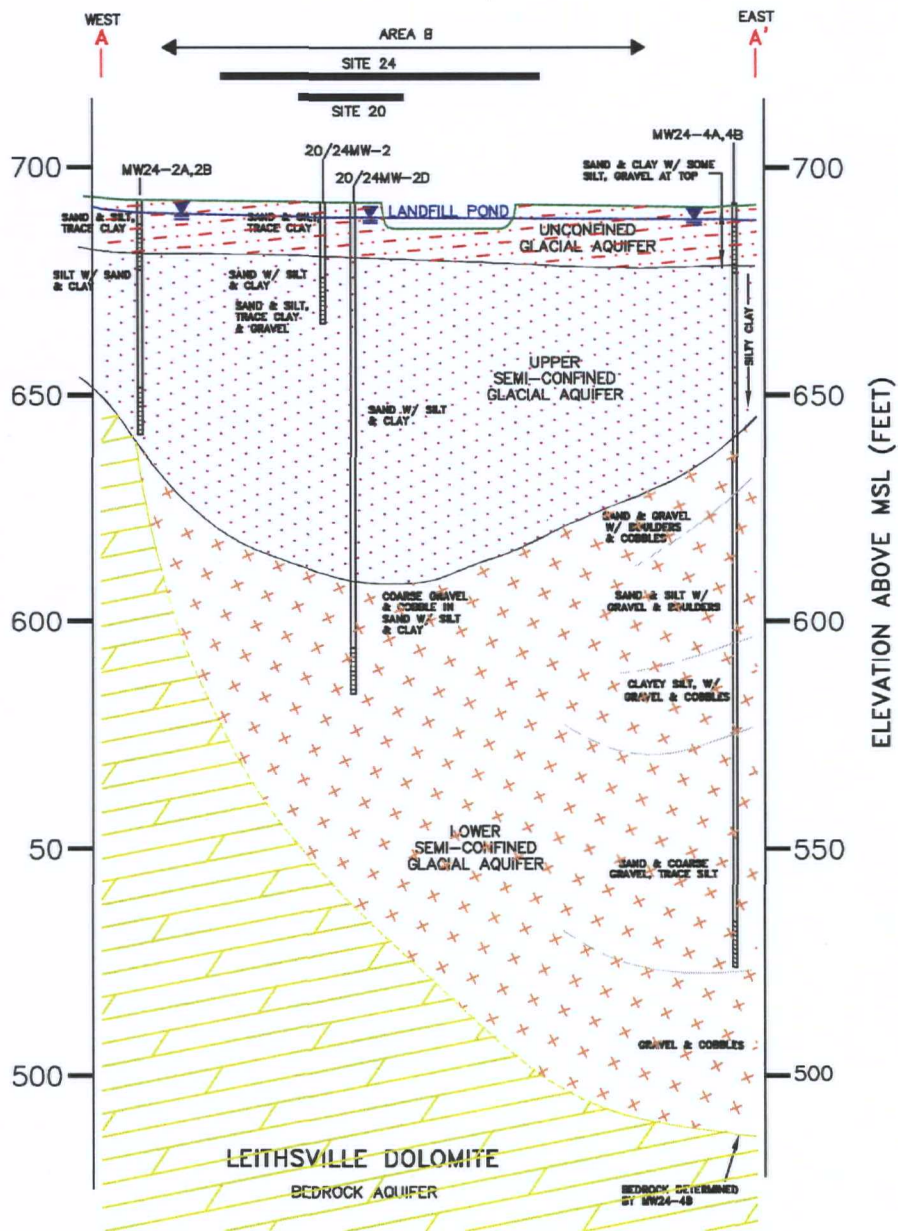
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Figure

3



LEGEND	
	MONITORING WELL
	SCREENED INTERVAL
	POTENTIOMETRIC SURFACE
	LAND SURFACE
	GEOLOGIC CONTACT
	INFERRED GEOLOGIC CONTACT

HORIZONTAL
0 500 1000 FT
VERTICAL EXAGGERATION = 12.5

PICATINNY ARSENAL
AREA B RECORD OF DECISION

AREA B GEOLOGIC
CROSS SECTION

DOVER, NEW JERSEY

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Figure

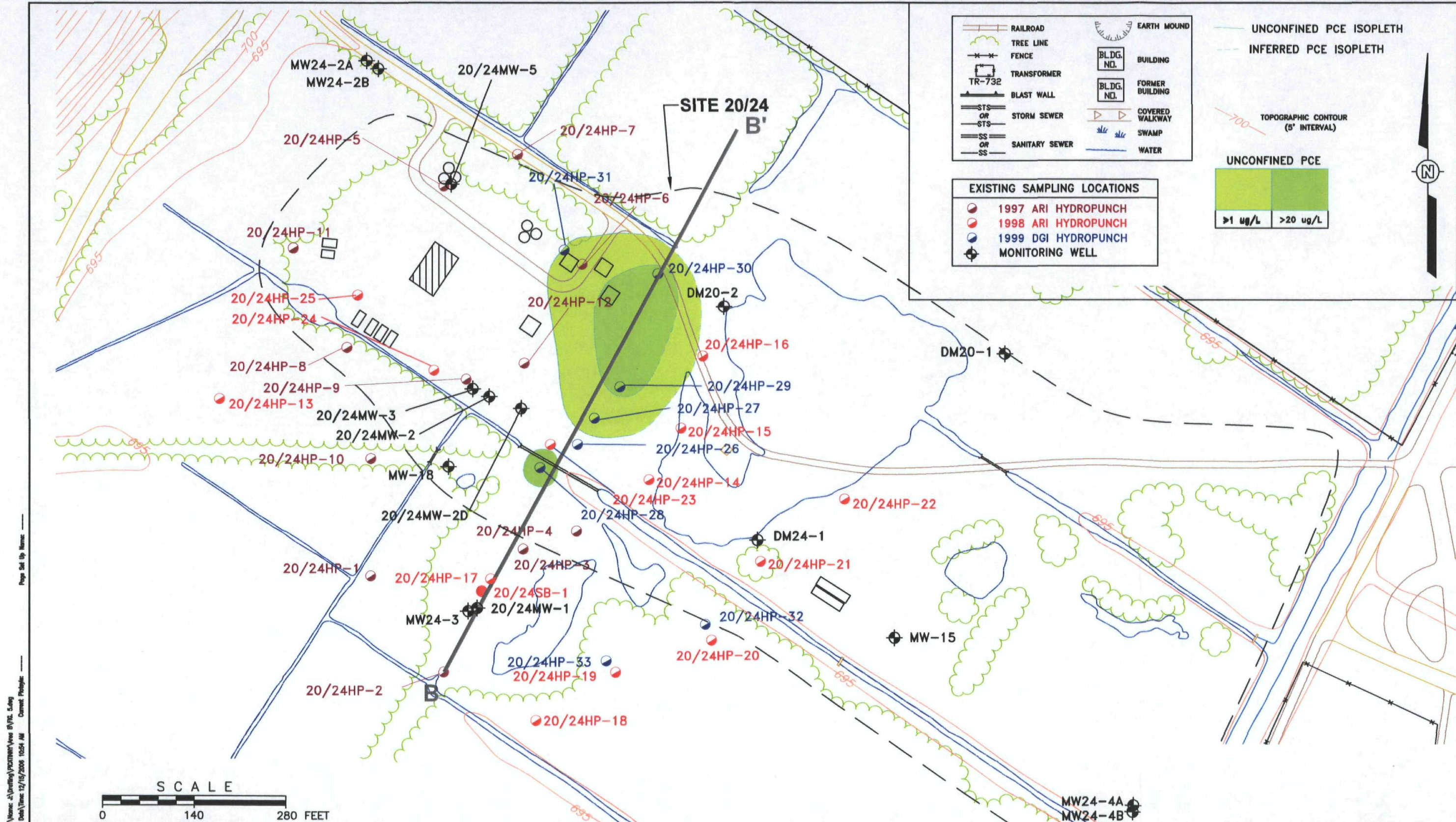
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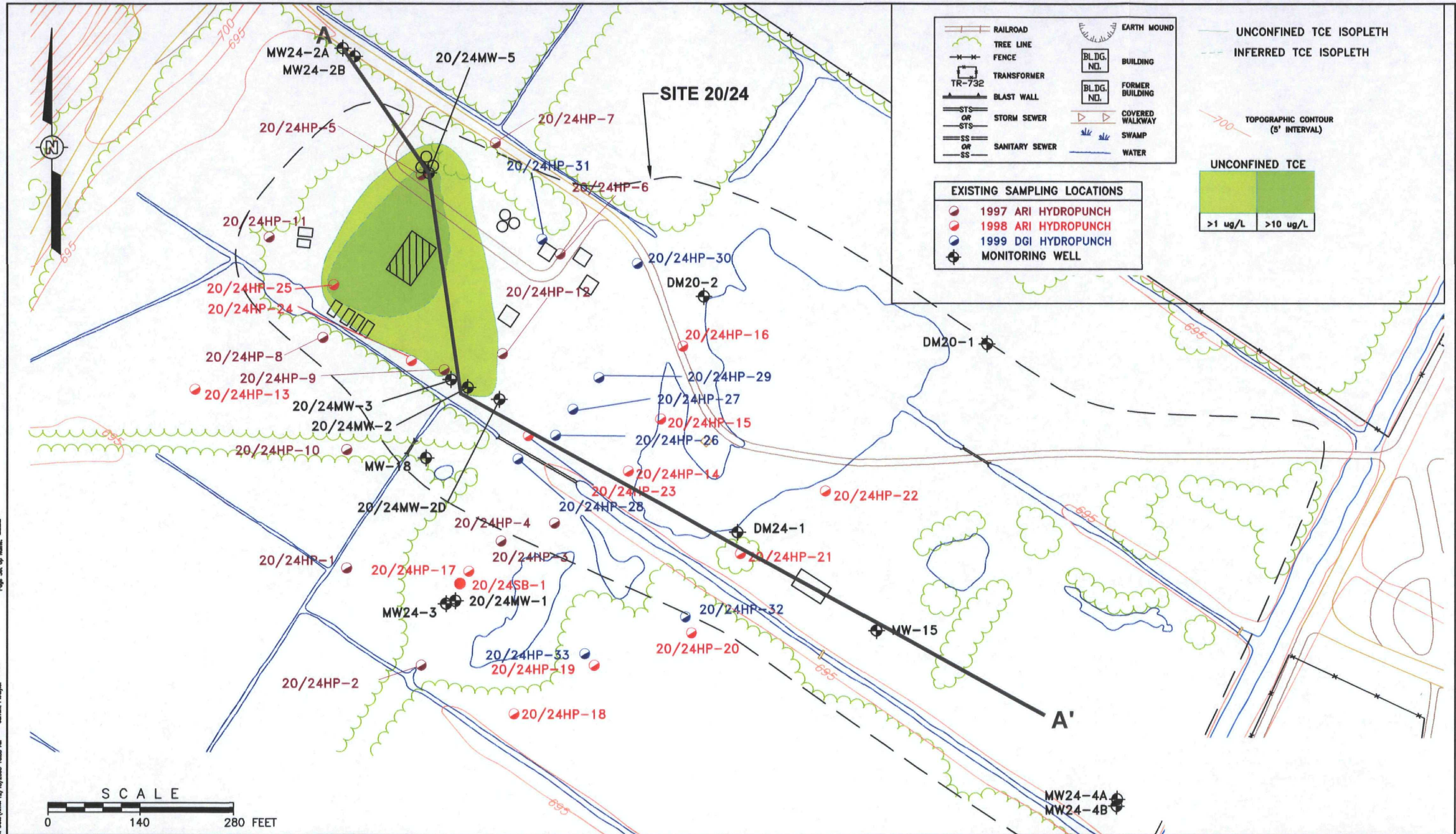
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Acad Version: 16.2 (US Tech)
User Name: Sunil, Arcadis
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RAILROAD	EARTH MOUND
TREE LINE	BLDG. NO.
FENCE	BUILDING
TRANSFORMER	BLDG. NO.
TR-732	FORMER BUILDING
BLAST WALL	COVERED WALKWAY
STS OR STS	SWAMP
SS OR SS	WATER
SANITARY SEWER	

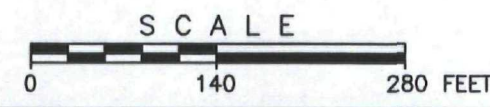
EXISTING SAMPLING LOCATIONS	
●	1997 ARI HYDROPUNCH
●	1998 ARI HYDROPUNCH
●	1999 DGI HYDROPUNCH
⊕	MONITORING WELL

UNCONFINED TCE ISOPLETH
INFERRED TCE ISOPLETH

TOPOGRAPHIC CONTOUR (5' INTERVAL)

UNCONFINED TCE

>1 ug/L	>10 ug/L
---------	----------



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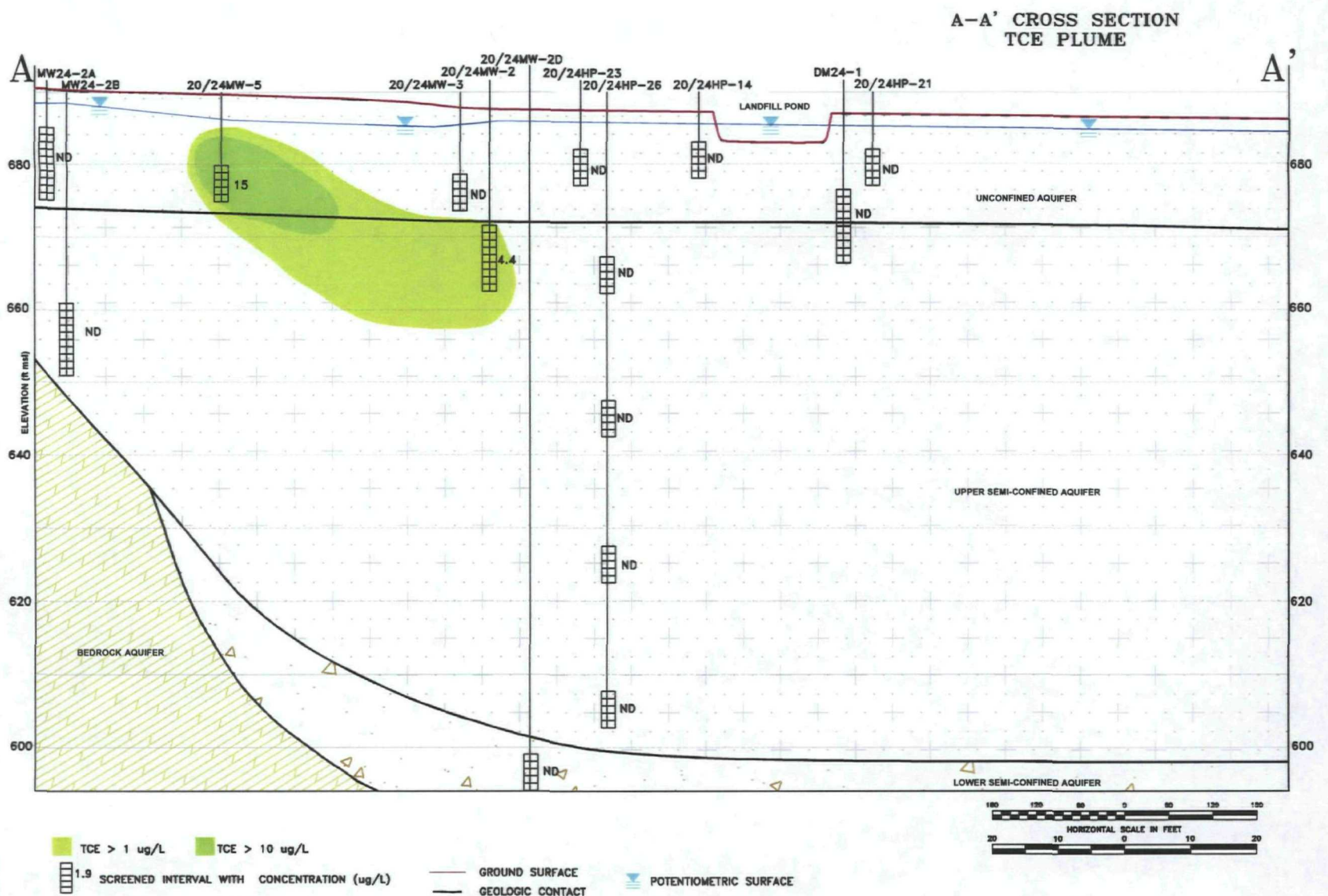
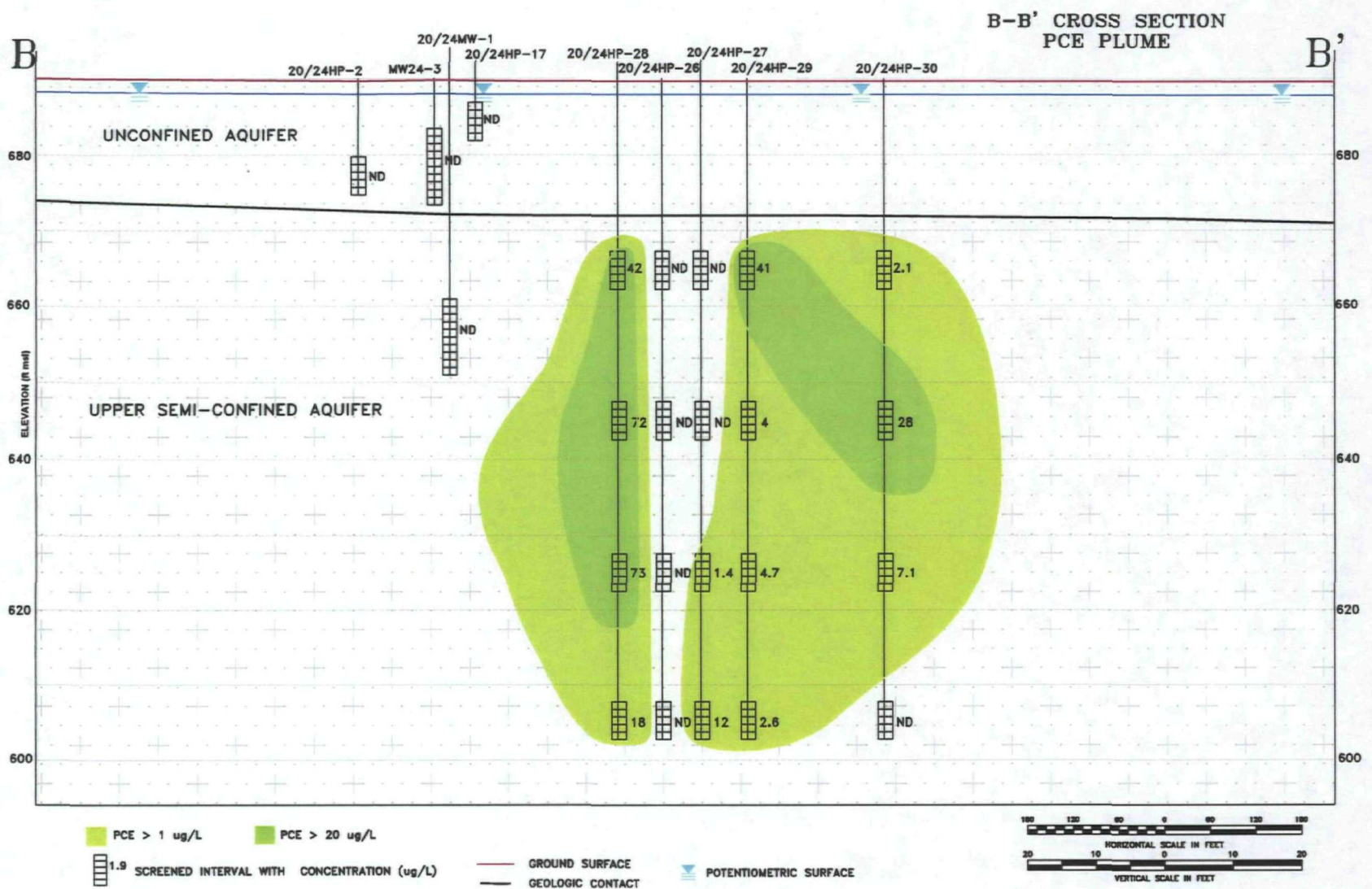
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PICATINNY ARESENAL
AREA B RECORD OF DECISION

LATERAL EXTENT OF
TCE CONTAMINATION

DOVER, NEW JERSEY

Project Number	GP06PICA.P205.NP001
Drawing Date	12/15/05
Figure	6



NOTE:
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PICATINNY ARSENAL
AREA B RECORD OF DECISION

VERTICAL EXTENT OF PCE & TCE CONTAMINATION BASED ON 1999 DGI

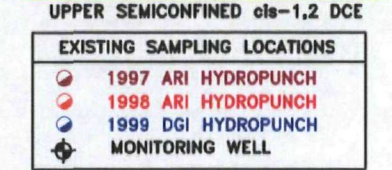
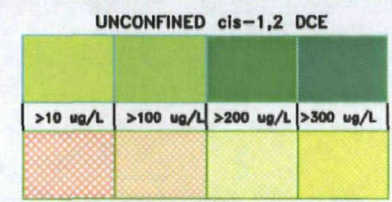
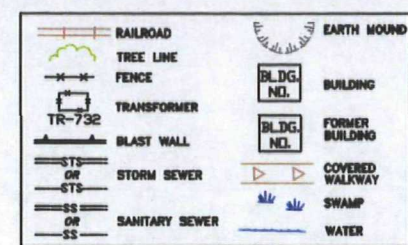
PCE B-B' CROSS SECTION &
TCE A-A' CROSS SECTION

DOVER, NEW JERSEY

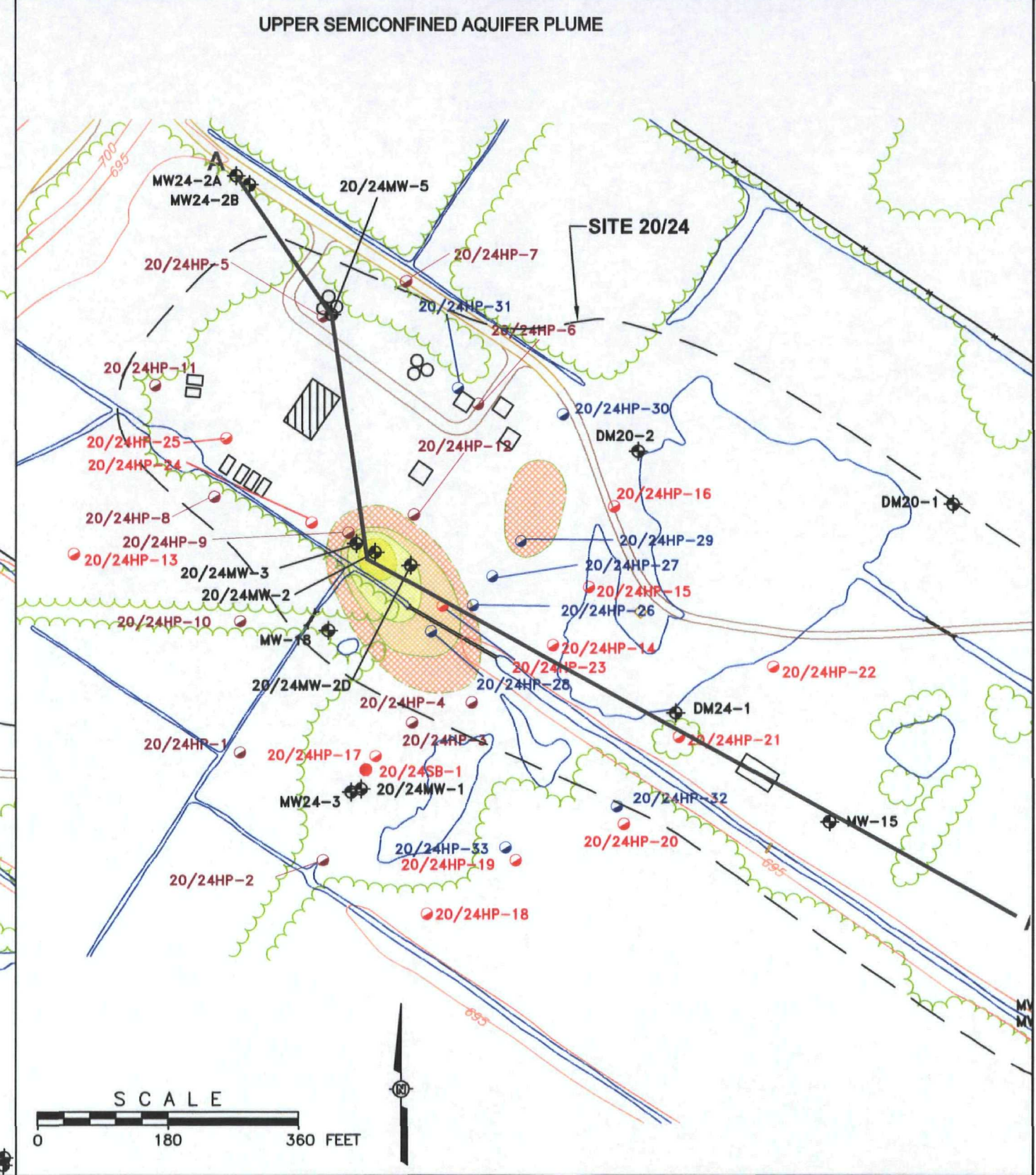
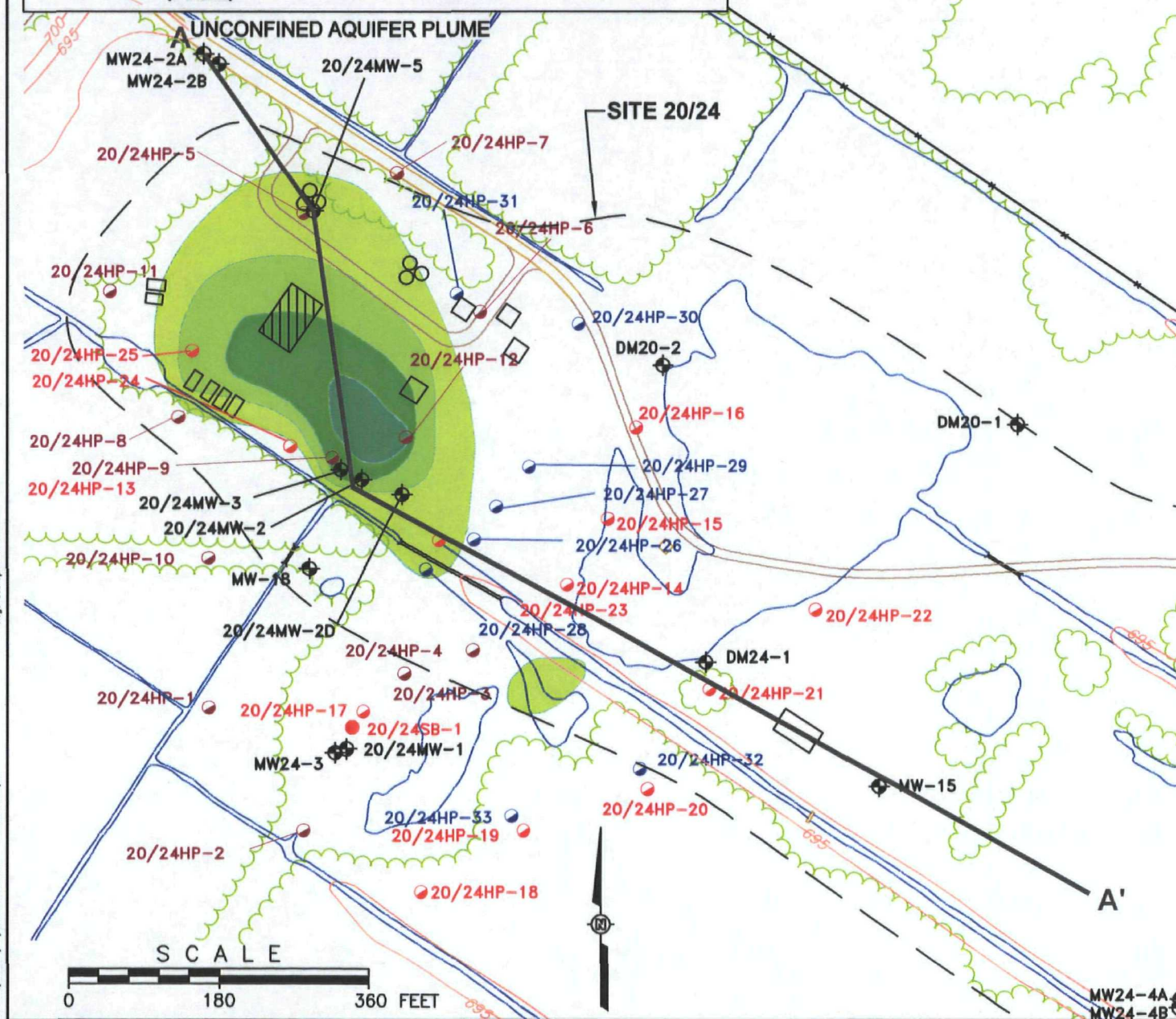
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Figure
7



NOTE: THE MOST RECENT SAMPLING DATA WAS USED FOR EACH SAMPLING POINT. THE HIGHEST CONCENTRATION WAS USED FOR HYDROPUNCH LOCATIONS WITH MULTIPLE DEPTH INTERVALS.

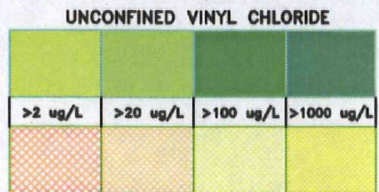
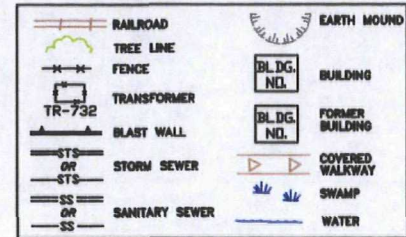


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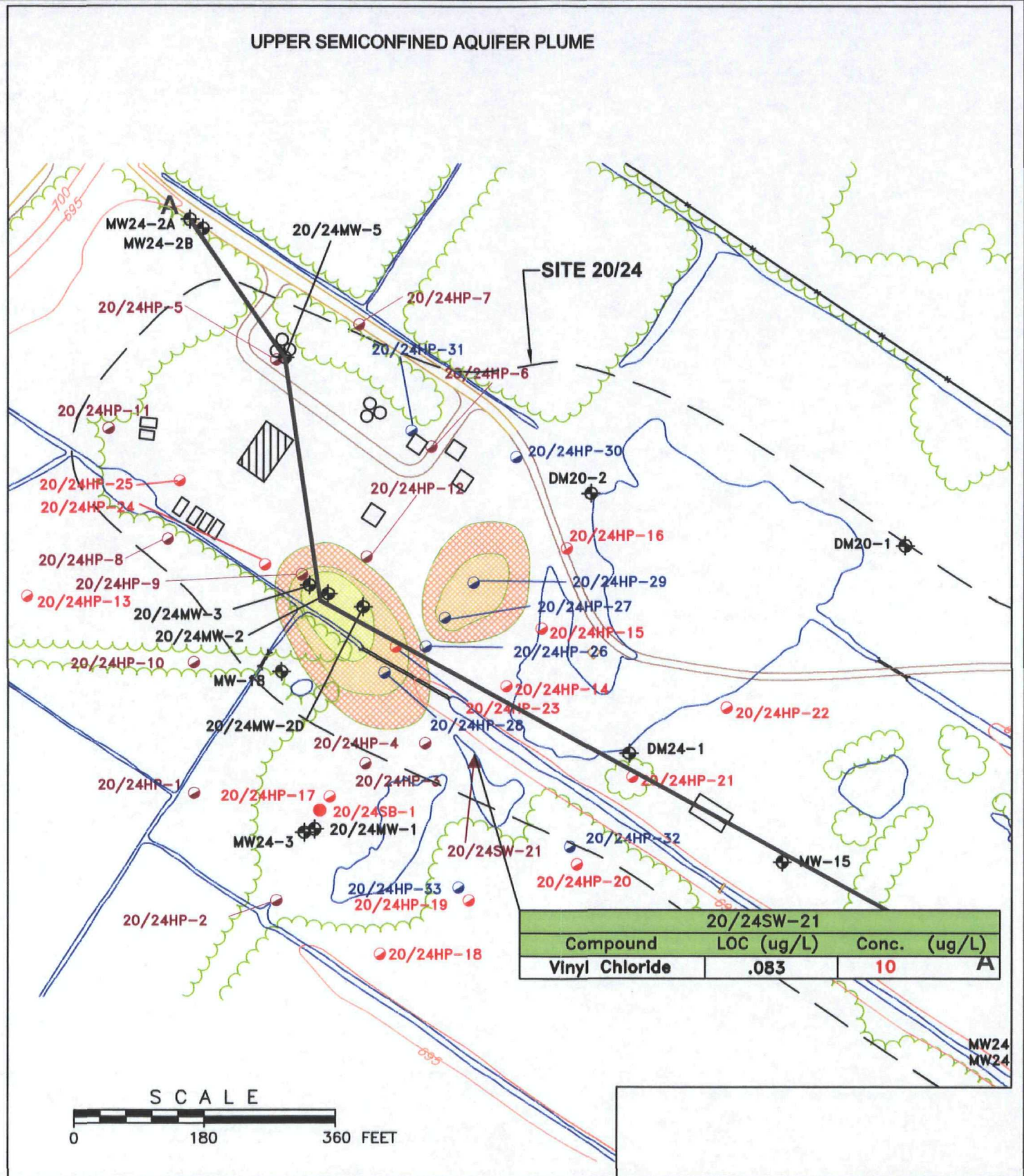
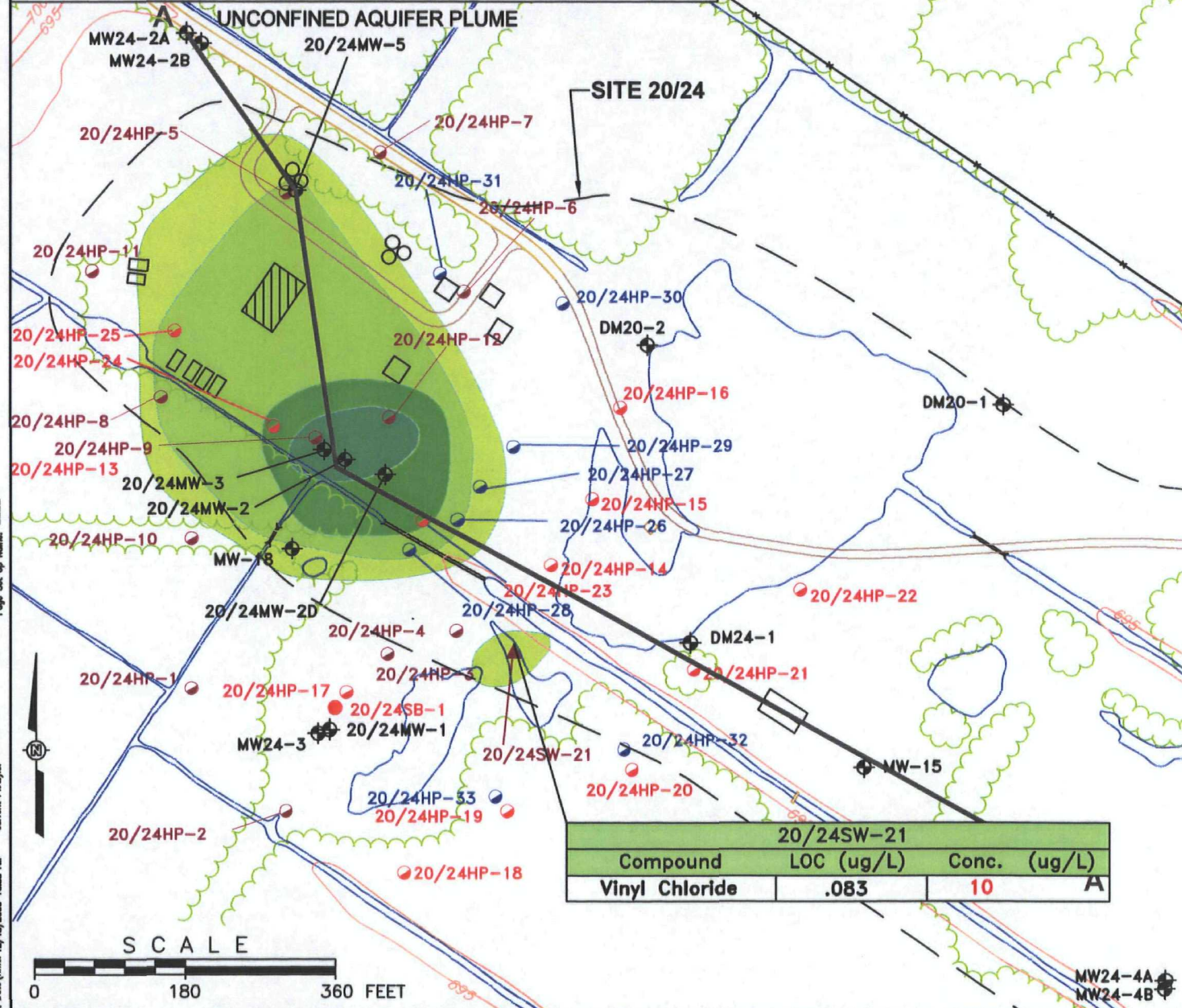
PICATINNY ARENAL
 AREA B RECORD OF DECISION
 LATERAL EXTENT OF
 cis-1,2 DCE CONTAMINATION
 DOVER, NEW JERSEY

Project Number GP06PICA.P205.NP001
Drawing Date 12/15/06
Figure 8



- EXISTING SAMPLING LOCATIONS**
- 1997 ARI HYDROPUNCH
 - 1997 ARI SURFACE WATER
 - 1998 ARI HYDROPUNCH
 - 1999 DGI HYDROPUNCH
 - MONITORING WELL

NOTE: THE MOST RECENT SAMPLING DATA WAS USED FOR EACH SAMPLING POINT. THE HIGHEST CONCENTRATION WAS USED FOR HYDROPUNCH LOCATIONS WITH MULTIPLE DEPTH INTERVALS.



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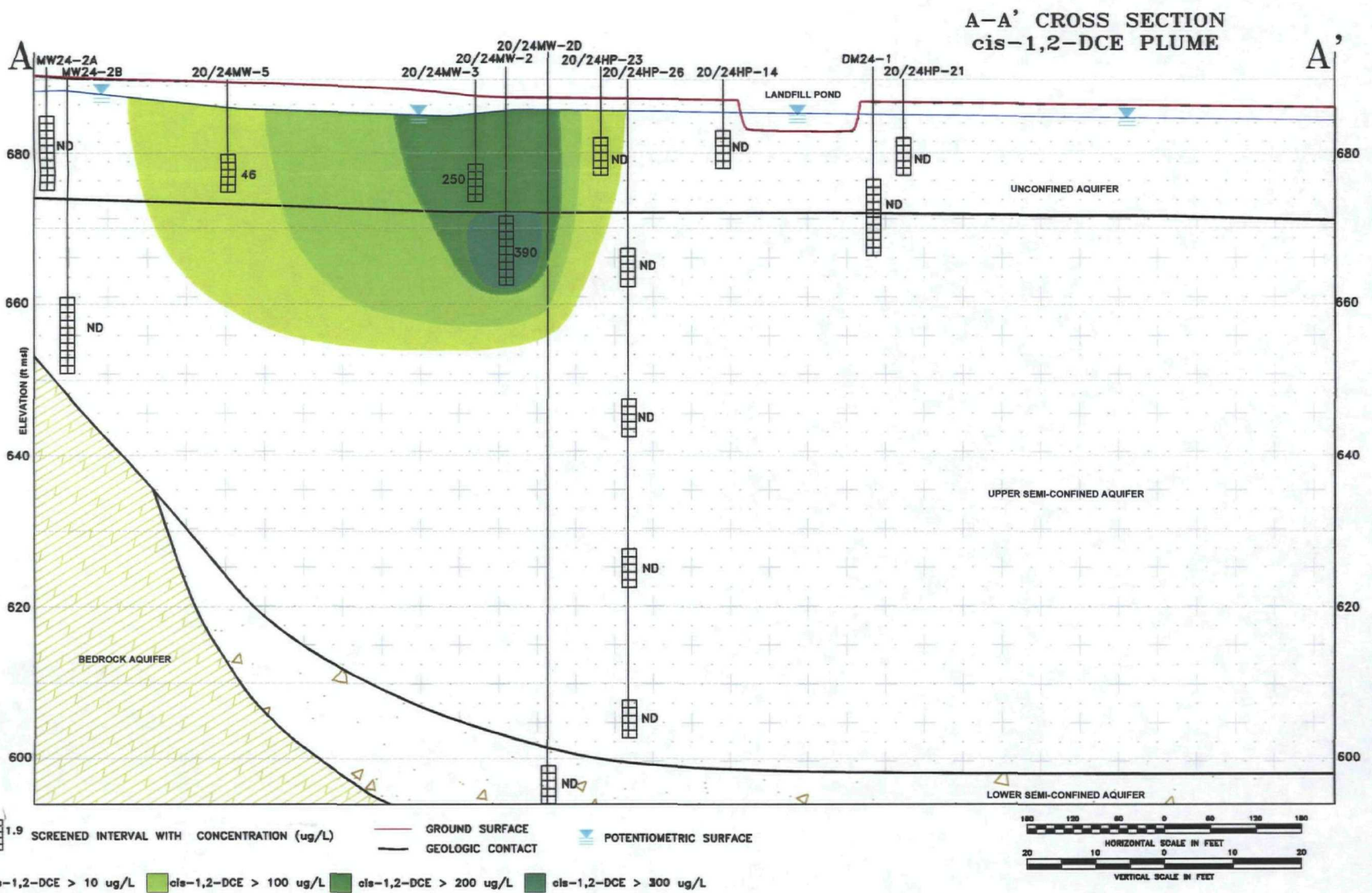
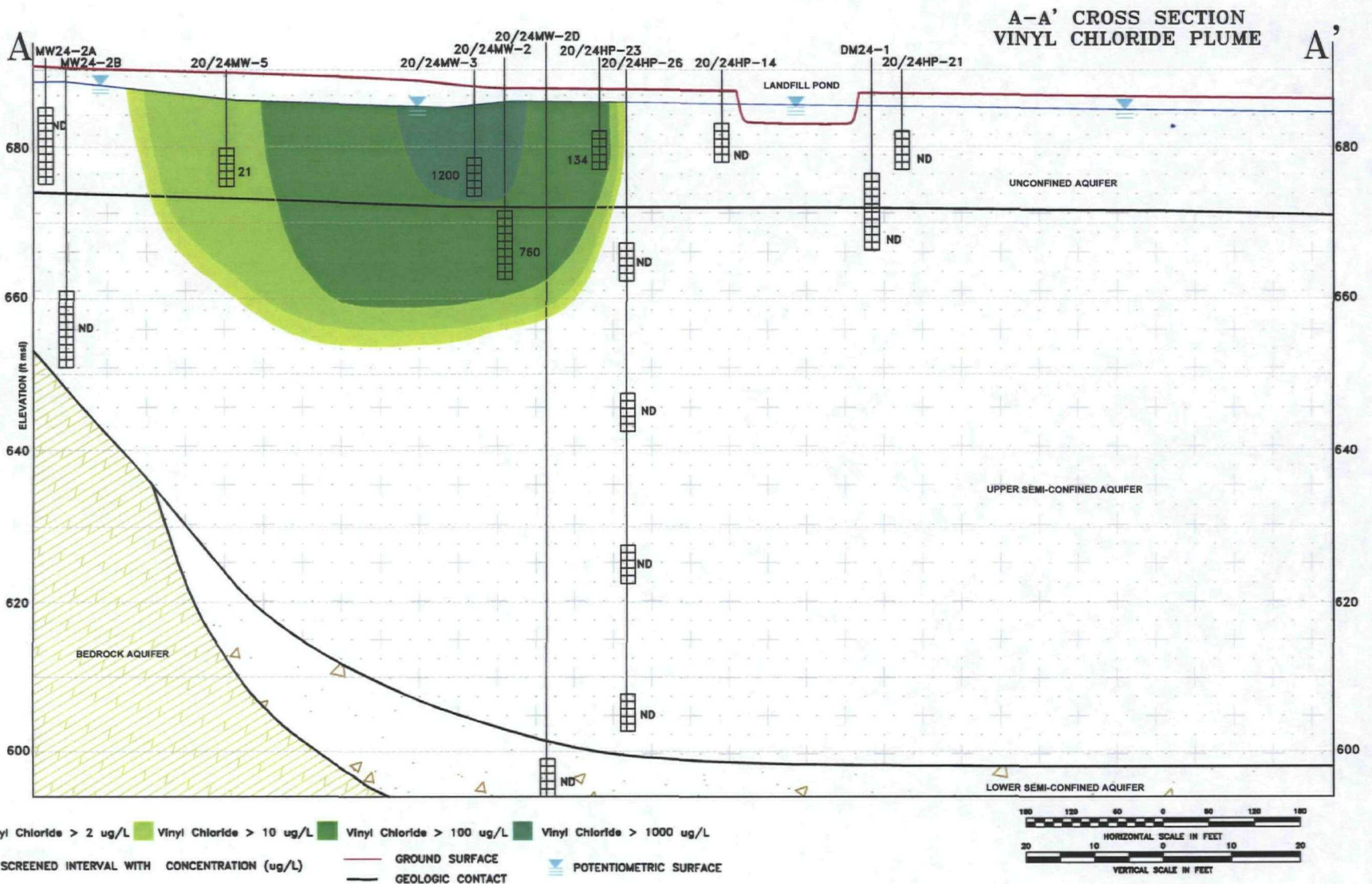
Technical Review
 K. EYRE

PICATINNY ARESENAL
 AREA B RECORD OF DECISION

LATERAL EXTENT OF
 VINYL CHLORIDE CONTAMINATION

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Figure	9



NOTE:
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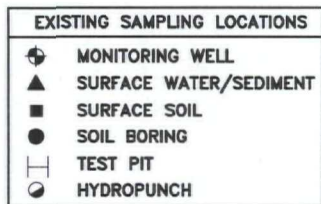
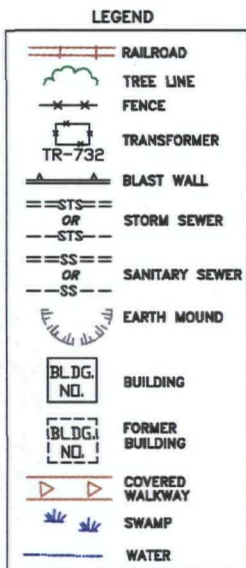
06

20/24MW-9

20/24MW-10

20/24MW-11

APPROXIMATE LOCATION
OF ZERO VALENT IRON
INJECTION



20/24MW-6

20/24MW-3

20/24MW-2

20/24MW-7

20/24MW-8

20/24MW-2D



PICATINNY ARSENAL
AREA B RECORD OF DECISION

AREA B
HRC PILOT STUDY INJECTION POINTS

DOVER, NEW JERSEY

Project Number
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Drawing Date
12/15/06

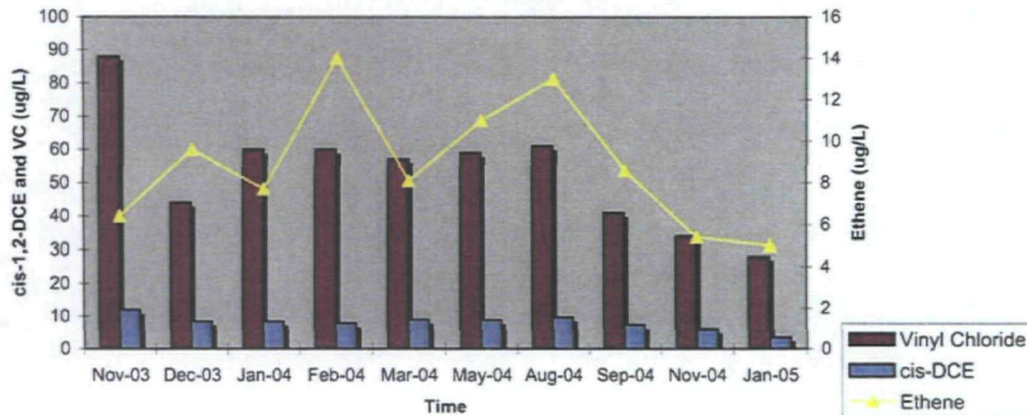
Figure
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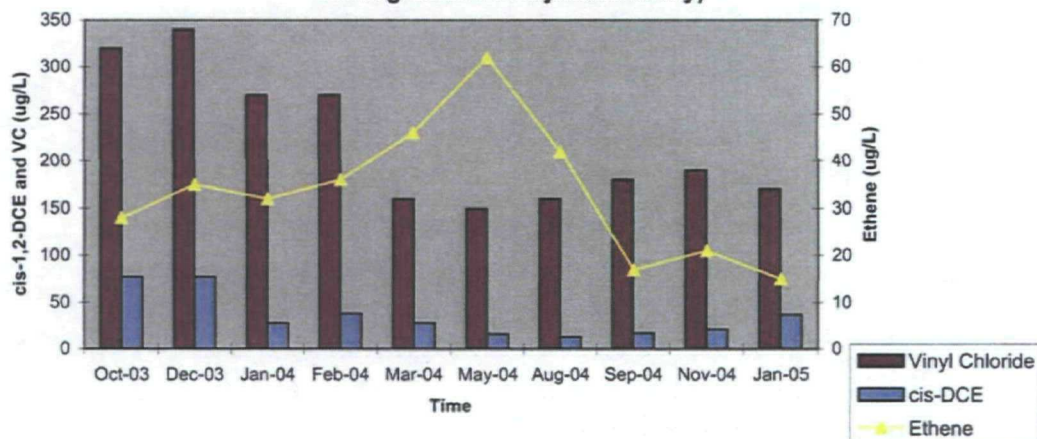
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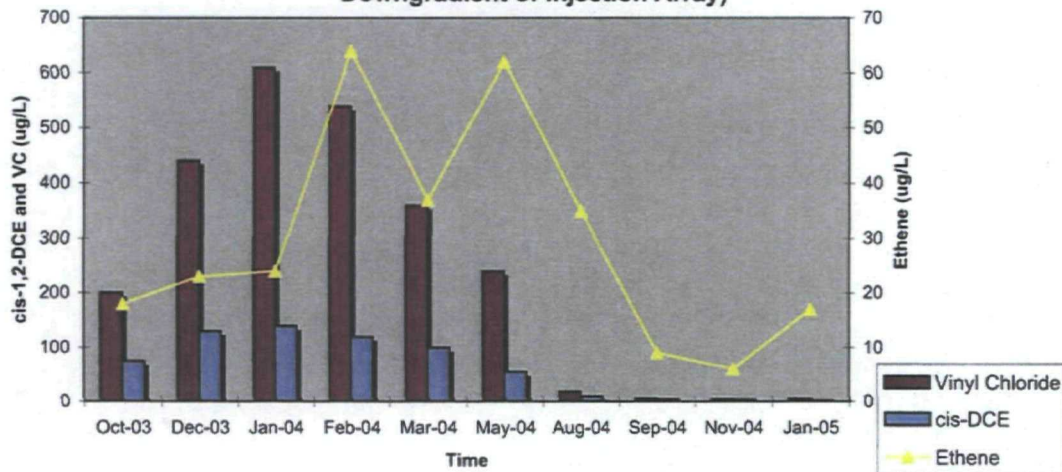
Concentrations of cis-1,2-DCE, VC, and Ethene in 20/24MW-6 (5-ft Upgradient of Injection Array)




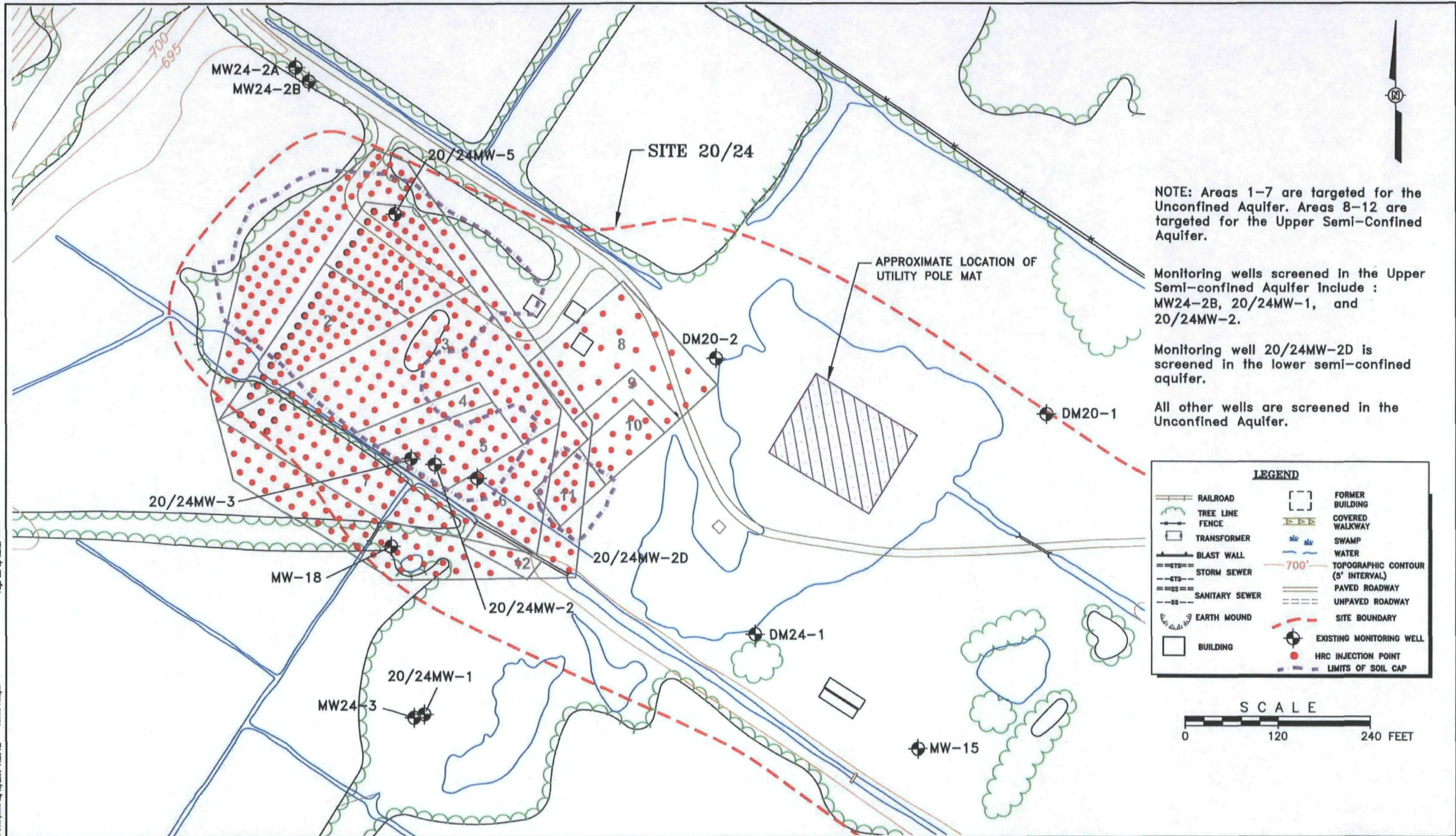
Concentrations of cis-1,2-DCE, VC, and Ethene in 20/24MW-7 (5-ft Downgradient of Injection Array)



Concentrations of cis-1,2-DCE, VC, and Ethene in 20/24MW-8 (10-ft Downgradient of Injection Array)




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Technical Review K. EYRE	

PICATINNY ARENAL
AREA B RECORD OF DECISION
ALTERNATIVE #5B AND 8 GROUNDWATER
TREATMENT WITH HRC
DOVER, NEW JERSEY

Project Number GP06PICA.P205.NP001
Drawing Date 12/15/06
Figure 13